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Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

2020 Annual Merit Review, Vehicle Technologies Office

Results Report

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Table of Contents

Introduction 1
Evaluation Criteria—Research & Development Subprogram Projects 2
Evaluation Criteria—Technology Integration Projects 4
Project Scoring 7
Reviewer Responses 9

1. Advanced Combustion Engines 1-1
Project Feedback 1-2
Presentation Number: ace001 Presentation Title: Heavy-Duty Diesel Combustion Principal Investigator: Mark Musculus (Sandia National Laboratories) 1-7
Presentation Number: ace022 Presentation Title: Joint Development and Coordination of Emissions Control Data and Models (Cross-cut Lean Exhaust Emissions Reduction Simulations (CLEERS) Analysis and Coordination) Principal Investigator: Josh Pihl (Oak Ridge National Laboratory) 1-11
Presentation Number: ace023 Presentation Title: CLEERS: Fundamentals in Selective Catalytic Reduction (SCR), Filter, and Protocol Principal Investigator: Yong Wang (Pacific Northwest National Laboratory) 1-15
Presentation Number: ace027 Presentation Title: Next-Generation Selective Catalytic Reduction (SCR)-Dosing System Investigation Principal Investigator: Abhijeet Karkamkar (Pacific Northwest National Laboratory) 1-18
Presentation Number: ace032 Presentation Title: Cummins-ORNL Emissions Cooperative Research and Development Agreement (CRADA): NOx Control and Measurement Technology for Heavy-Duty Diesel Engines, Self-Diagnosing SmartCatalyst Systems Principal Investigator: Bill Partridge (Oak Ridge National Laboratory) 1-22
Presentation Number: ace033 Presentation Title: Emission Control for Lean Gasoline Engines Principal Investigator: Vitaly Prikhodko (Oak Ridge National Laboratory) 1-27
Presentation Number: ace056 Presentation Title: Low-Temperature Oxidation Principal Investigator: Yong Wang (Pacific Northwest National Laboratory) 1-31
Presentation Number: ace085 Presentation Title: Low-Temperature Emission Control to Enable Fuel-Efficient Engine Commercialization Principal Investigator: Todd Toops (Oak Ridge National Laboratory) 1-37
Presentation Number: ace100 Presentation Title: Improving Transportation Efficiency through Integrated Vehicle, Engine, and Powertrain Research - SuperTruck 2 Principal Investigator: Darek Villeneuve (Daimler Trucks North America) 1-40
Presentation Number: ace101 Presentation Title: Volvo SuperTruck 2: Pathway to Cost-Effective Commercialized Freight Efficiency Principal Investigator: Pascal Amar (Volvo Trucks North America) 1-46
Presentation Number: ace102 Presentation Title: Cummins-Peterbilt SuperTruck 2 Principal Investigator: Jon Dickson (Cummins-Peterbilt) 1-52
Presentation Number: ace103 Presentation Title: Development and Demonstration of a Fuel-Efficient Class 8 Tractor and Trailer SuperTruck Principal Investigator: Russell Zukouski (Navistar) 1-58

Presentation Number: ace118 Presentation Title: CLEERS Passive NOx Adsorber (PNA) Principal Investigator: Janos Szanyi (Pacific Northwest National Laboratory) 1-63

Presentation Number: ace119 Presentation Title: Development and Optimization of a Multi-Functional SCR-DPF (Diesel Particulate Filter) Aftertreatment System for Heavy-Duty NOx and Soot Emission Reduction Principal Investigator: Ken Rappe (Pacific Northwest National Laboratory) 1-66

Presentation Number: ace123 Presentation Title: Temperature-Following Thermal Barrier Coatings for High-Efficiency Engines Principal Investigator: Tobias Schaedler (HRL Laboratories)........................1-69

Presentation Number: ace124 Presentation Title: SuperTruck 2 - PACCAR Principal Investigator: Maarten Meijer (PACCAR) 1-72

Presentation Number: ace128 Presentation Title: Reduced Precious Metal Catalysts for Methane and NOx Emission Control of Natural Gas Vehicles Principal Investigator: Michael Harold (University of Houston)........................1-77

Presentation Number: ace129 Presentation Title: Design and Optimization of Structured Multi-Functional Trapping Catalysts for Conversion of Hydrocarbons and NOx from Diesel and Advanced Combustion Engines Principal Investigator: Michael Harold (University of Houston) 1-82

Presentation Number: ace130 Presentation Title: Development of Passive Hydrocarbon/NOx Trap Catalysts for Low-Temperature Gasoline Applications Principal Investigator: Mark Crocker (University of Kentucky)........................1-86

Presentation Number: ace135 Presentation Title: Toward Predictive Nozzle Flow and Combustion Simulations for Compression Ignition Engines Principal Investigator: Gina Magnotti (Argonne National Laboratory) 1-90

Presentation Number: ace136 Presentation Title: Medium-Duty Diesel Combustion Principal Investigator: Stephen Busch (Sandia National Laboratories)........................1-93

Presentation Number: ace138 Presentation Title: Partnership for Advanced Combustion Engines (PACE) - A Light-Duty National Laboratory Combustion Consortium Principal Investigator: Paul Miles (Sandia National Laboratories)........................1-96

Presentation Number: ace139 Presentation Title: Development of an Optimized Gasoline Surrogate Formulation for PACE Experiments and Simulations Principal Investigator: Scott Wagnon (Lawrence Livermore National Laboratory)........................1-101

Presentation Number: ace140 Presentation Title: Improved Chemical Kinetics and Algorithms for More Accurate, Faster Simulations Principal Investigator: Russell Whitesides (Lawrence Livermore National Laboratory)........................1-106

Presentation Number: ace141 Presentation Title: Advanced Ignition System Fundamentals Principal Investigator: Isaac Ekoto (Sandia National Laboratories) 1-110

Presentation Number: ace142 Presentation Title: Development and Validation of Simulation Tools for Advanced Ignition Systems Principal Investigator: Riccardo Scarcelli (Argonne National Laboratory) 1-114

Presentation Number: ace143 Presentation Title: Fuel Injection and Spray Research Principal Investigator: Chris Powell (Argonne National Laboratory) 1-118

Presentation Number: ace144 Presentation Title: Spray Wall Interactions and Soot Formation Principal Investigator: Lyle Pickett (Sandia National Laboratories)........................1-122

Presentation Number: ace145 Presentation Title: More Accurate Modeling of Heat Transfer in Internal Combustion Engines Principal Investigator: K. Dean Edwards (Oak Ridge National Laboratory) 1-127

Presentation Number: ace146 Presentation Title: Direct Numerical Simulation (DNS) and High-Fidelity Large-Eddy Simulation (LES) for Improved Prediction of In-Cylinder Flow and Combustion Processes Principal Investigator: Muhsin Ameen (Argonne National Laboratory) . 1-131

Presentation Number: ace147 Presentation Title: Mitigation of Knock and Low-Speed Pre-Ignition (LSPI) for High-Power Density Engines Principal Investigator: Jim Szybist (Oak Ridge National Laboratory) 1-135

Presentation Number: ace148 Presentation Title: Overcoming Barriers for Dilute Combustion Principal Investigator: Brian Kaul (Oak Ridge National Laboratory) 1-138

Presentation Number: ace149 Presentation Title: Cold-Start Physics and Chemistry in Combustion Systems for Emissions Reduction Principal Investigator: Scott Curran (Oak Ridge National Laboratory) 1-142

Presentation Number: ace150 Presentation Title: Enabling Low-Temperature Plasma (LTP) Ignition Technologies for Multi-Mode Engines through the Development of a Validated High-Fidelity LTP Model for Predictive Simulation Tools Principal Investigator: Nick Tsolas (Auburn University) 1-147

Presentation Number: ace151 Presentation Title: Hierarchically Informed Engineering Models for Predictive Modeling of Turbulent Premixed Flame Propagation in Pre-Chamber Turbulent Jet Ignition Principal Investigator: Haifeng Wang (Purdue University) 1-152

Presentation Number: ace152 Presentation Title: Development of High-Fidelity and Efficient Modeling Capabilities for Enabling Co-Optimization of Fuels and Multi-Mode Engines Principal Investigator: Matthias Ihme (Stanford University) 1-156

Presentation Number: ace153 Presentation Title: Chemistry of Cold-Start Emissions and Impact of Emissions Control Principal Investigator: Melanie Moses-DeBusk (Oak Ridge National Laboratory) 1-160

Presentation Number: ace154 Presentation Title: Heavy-Duty Hybrid Diesel Engine with Front-End Accessory Drive-Integrated Energy Storage Principal Investigator: Chad Koci (Caterpillar) 1-163

Presentation Number: ace155 Presentation Title: Low-Mass and High-Efficiency Engine for Medium-Duty Truck Applications Principal Investigator: Qigui Wang (General Motors) 1-167

Presentation Number: ace156 Presentation Title: Next-Generation, High-Efficiency Boosted Engine Development Principal Investigator: Michael Shelby (Ford) 1-171

Presentation Number: ace157 Presentation Title: Low-Temperature Gasoline Combustion for High-Efficiency Medium- and Heavy-Duty Engines Principal Investigator: John Dec (Sandia National Laboratories) 1-175

Acronyms and Abbreviations 1-179

2. Batteries R&D 2-1

Project Feedback 2-2

Presentation Number: bat049 Presentation Title: Tailoring Integrated Layered- and Spinel-Electrode Structures for High-Capacity Lithium-Ion Cells Principal Investigator: Jason Croy (Argonne National Laboratory) 2-9

Presentation Number: bat240 Presentation Title: High-Energy Anode Material Development for Lithium-Ion Batteries Principal Investigator: Cary Hayner (NanoGraf) 2-13

Presentation Number: bat247 Presentation Title: Fast-Charge and Low-Cost Lithium Ion Batteries for Electric Vehicles Principal Investigator: Herman Lopez (Zenlabs Energy) 2-18

Presentation Number: bat251 Presentation Title: Cathode Materials for Next Generation Lithium-Ion Batteries: Design, Synthesis, and Characterization of Low-Cobalt Cathodes Principal Investigator: Jason Croy (Argonne National Laboratory) 2-23

Presentation Number: bat252 Presentation Title: Cathode Materials for Next Generation Lithium-Ion Batteries: Diagnostic Testing and Evaluation of Low-Cobalt Cathodes Principal Investigator: Dan Abraham (Argonne National Laboratory) 2-27

Presentation Number: bat253 Presentation Title: Cathode Materials for Next Generation Lithium-Ion Batteries: Theory and Modeling of Low-Cobalt Cathodes Principal Investigator: Hakim Iddir (Argonne National Laboratory) 2-31

Presentation Number: bat293 Presentation Title: A Closed-Loop Process for End-of-Life Electric Vehicle Lithium-Ion Batteries Principal Investigator: Yan Wang (Worcester Polytechnic Institute) 2-35

Presentation Number: bat332 Presentation Title: High Electrode-Loading Electric Vehicle Cell Principal Investigator: Mohamed Taggougui (24M Technologies) 2-39

Presentation Number: bat355 Presentation Title: Development of High-Performance Lithium-Ion Cell Technology for Electric Vehicle Applications Principal Investigator: Madhuri Thakur (Farasis Energy) 2-43

Presentation Number: bat356 Presentation Title: Lithium-Ion Cell Manufacturing Using Directly Recycled Active Materials Principal Investigator: Mike Slater (Farasis Energy) 2-47

Presentation Number: bat357 Presentation Title: Thicker Cathode Coatings for Lithium-Ion Electric Vehicle Batteries Principal Investigator: Stuart Hellring (PPG Industries) 2-52

Presentation Number: bat359 Presentation Title: Status and Challenges of Electrode Materials for High-Energy Cells Principal Investigator: Stanley Whittingham (Binghamton University) .. 2-57

Presentation Number: bat360 Presentation Title: Scale-Up Optimization and Characterization of High-Nickel Cathodes Principal Investigator: Arumugam Manthiram (University of Texas at Austin) 2-60

Presentation Number: bat361 Presentation Title: Understanding Electrode Interface Through Cryogenic Electron Microscopy Principal Investigator: Yi Cui (Stanford University/SLAC) 2-63

Presentation Number: bat362 Presentation Title: Lithium-Metal Anodes: Problems and Multiple Solutions Based on Hosts, Interphase, and Electrolytes Principal Investigator: Jason Zhang (Pacific Northwest National Laboratory) 2-66

Presentation Number: bat364 Presentation Title: Surface Coating for High-Energy Cathode Principal Investigator: Jihui Yang (University of Washington) 2-69

Presentation Number: bat365 Presentation Title: Stabilizing Lithium-Metal Anode by Interfacial Layer Principal Investigator: Zhenan Bao (Stanford University/SLAC) 2-72

Presentation Number: bat366 Presentation Title: Advanced Imaging and Quantitative Characterization of Lithium-Metal Anode and Its Solid Electrolyte Interphase (SEI) Principal Investigator: Shirley Meng (University of California at San Diego) 2-77

Presentation Number: bat367 Presentation Title: Characterization Studies on Li-Metal Anode and High-Ni Cathode Materials Principal Investigator: Peter Khalifah (Brookhaven National Laboratory) 2-80

Presentation Number: bat368 Presentation Title: Battery500 Integrated Cell Diagnostics and Modeling to Identify Critical Gaps in Achieving High Cycle Life Principal Investigator: Eric Dufek (Idaho National Laboratory) 2-82

Presentation Number: bat369 Presentation Title: High-Energy Rechargeable Lithium-Metal Cells: Fabrication and Integration Principal Investigator: Jie Xiao (Pacific Northwest National Laboratory) 2-85

Presentation Number: bat370 Presentation Title: Advanced Diagnostics of Nickel-Rich, Layered-Oxide Secondary Particles Principal Investigator: Mike Toney (Stanford University/SLAC) 2-89

Presentation Number: bat376 Presentation Title: Disordered Rocksalt Transition-Metal Oxides (TMOs): Recent Advances Principal Investigator: Gerbrand Ceder (Lawrence Berkeley National Laboratory) 2-93

Presentation Number: bat388 Presentation Title: Silicon Deep Dive: Update and Overview Principal Investigator: Jack Vaughey (Argonne National Laboratory) 2-97

Presentation Number: bat392 Presentation Title: Enabling Rapid Charging in Lithium-Ion Batteries via Integrated Acoustofluidics Principal Investigator: James Friend (University of California at San Diego) 2-102

Presentation Number: bat393 Presentation Title: Development of an Extreme Fast-Charging Battery Principal Investigator: Chao Wang-Yang (Penn State University) 2-106

Presentation Number: bat394 Presentation Title: Highly Ordered Hierarchical Anodes for Extreme Fast-Charging Batteries Principal Investigator: Neil Dasgupta (University of Michigan) 2-110

Presentation Number: bat395 Presentation Title: Developing Safe, High-Energy, Fast-Charge Batteries for Automobiles Principal Investigator: Wenjuan Mattis (Microvast, Inc.) 2-114

Presentation Number: bat396 Presentation Title: Enabling Extreme Fast Charging through Anode Modification Principal Investigator: Esther Takeuchi (Stony Brook University) 2-117

Presentation Number: bat397 Presentation Title: Titanium Niobium Oxide-Based Lithium-Ion Batteries for Extreme Fast-Charging Applications Principal Investigator: Sheng Dai (University of Tennessee at Knoxville) 2-120

Presentation Number: bat398 Presentation Title: Extreme Fast-Charging Lithium-Ion Batteries Principal Investigator: Edward Buiel (Edward Buiel Consulting, LLC) 2-124

Presentation Number: bat400 Presentation Title: Novel Liquid/Oligomer Hybrid Electrolyte with High Lithium-Ion Transference Number (Hi-LiT) for Extreme Fast Charging Principal Investigator: Zhijia Du (Oak Ridge National Laboratory) 2-127

Presentation Number: bat401 Presentation Title: Advanced Electrolytes for Extreme Fast Charging Principal Investigator: William Chueh (Stanford University) 2-130

Presentation Number: bat404 Presentation Title: Direct Fluorination of Disordered Rock Salt Cathode Oxides: Synthesis and Characterization Principal Investigator: Jagit Nanda (Oak Ridge National Laboratory) 2-133

Presentation Number: bat405 Presentation Title: Advanced Microscopies of Next-Generation Lithium-Ion Battery Cathode Materials Principal Investigator: Chongmin Wang (Pacific Northwest National Laboratory) 2-137

Presentation Number: bat406 Presentation Title: Disordered Rocksalt Transition-Metal Oxides (TMOs): Synthetic Strategies Principal Investigator: Guoying Chen (Lawrence Berkeley National Laboratory) 2-140

Presentation Number: bat411 Presentation Title: Aerosol Manufacturing Technology for Production of Low-Cobalt Lithium-Ion Battery Cathodes Principal Investigator: Toivo Kodas (Cabot Corporation) 2-144

Presentation Number: bat412 Presentation Title: Novel Lithium-Iron and Aluminum Nickelate (NFA) as Advanced Cobalt-Free Cathode Materials Principal Investigator: Ilias Belharouak (Oak Ridge National Laboratory) 2-147

Presentation Number: bat413 Presentation Title: High-Performance, Low-Cobalt Cathode Materials for Lithium-Ion Batteries Principal Investigator: Donghai Wang (Penn State University) 2-150

Presentation Number: bat414 Presentation Title: Enhancing Oxygen Stability in Low-Cobalt, Layered-Oxide Cathode Materials Principal Investigator: Huolin Xin (University of California at Irvine) 2-153

Presentation Number: bat415 Presentation Title: High-Nickel Cathode Materials for High-Energy, Long-Life, Low-Cost Lithium-Ion Batteries Principal Investigator: Arumugam Manthiram (University of Texas at Austin) 2-157

Presentation Number: bat416 Presentation Title: Cobalt-Free Cathode Materials and Their Novel Architectures Principal Investigator: Shirley Meng (University of California at San Diego) 2-160

Presentation Number: bat417 Presentation Title: Cobalt-Free Cathodes for Next-Generation Lithium-Ion Batteries Principal Investigator: Neil Kidner (Nexceris) 2-163

Presentation Number: bat436 Presentation Title: Silicon Electrolyte Interface Stabilization (SEISTA): Update and Overview Principal Investigator: Tony Burrell (National Renewable Energy Laboratory) 2-166

Presentation Number: bat437 Presentation Title: Silicon Electrolyte Interface Stabilization (SEISTA): Electrochemical Methods Principal Investigator: Robert Kostecki (Lawrence Berkeley National Laboratory) 2-171

Presentation Number: bat438 Presentation Title: Silicon Electrolyte Interface Stabilization (SEISTA): Advanced Characterization Principal Investigator: Glen Teeter (National Renewable Energy Laboratory) 2-175

Presentation Number: bat439 Presentation Title: Silicon Deep Dive: Silicon-Based Slurries and Electrodes Principal Investigator: Beth Armstrong (Oak Ridge National Laboratory) 2-179

Presentation Number: bat440 Presentation Title: Silicon Deep Dive: Silicon Functionalization Principal Investigator: Zhengcheng Zhang (Argonne National Laboratory) 2-183

Presentation Number: bat441 Presentation Title: High-Performance Electrolyte for Lithium-Nickel-Manganese Oxide (LNMO)/Lithium-Titanate (LTO) Batteries Principal Investigator: Jennifer Hoffman (Gotion) 2-187

Presentation Number: bat442 Presentation Title: Behind-the-Meter-Storage (BTMS) Overview Principal Investigator: Anthony Burrell (National Renewable Energy Laboratory) 2-192

Presentation Number: bat444 Presentation Title: Highly Loaded Sulfur Cathode, Coated Separator, and Gel Electrolyte for High-Rate Lithium-Sulfur Battery Principal Investigator: Yong Joo (Cornell University) 2-195

Presentation Number: bat445 Presentation Title: Multifunctional Lithium-Ion Conducting Interfacial Materials for Lithium-Metal Batteries Principal Investigator: Donghai Wang (Penn State University) 2-200

Presentation Number: bat446 Presentation Title: Electrochemically Stable, High-Energy Density Lithium-Sulfur Batteries Principal Investigator: Prashant Kumta (University of Pittsburgh) 2-203

Presentation Number: bat447 Presentation Title: 3-D Printed, Low-Tortuosity Garnet Framework for Beyond 500 Wh/kg Batteries Principal Investigator: Eric Wachsman (University of Maryland) 2-206

Presentation Number: bat448 Presentation Title: Advanced Electrolyte Supporting 500 Wh/kg Lithium-Carbon/Nickel Manganese Cobalt (NMC) Batteries Principal Investigator: Chunsheng Wang (University of Maryland) 2-209

Presentation Number: bat449 Presentation Title: Controlled Interfacial Phenomena for Extended Battery Life Principal Investigator: Perla Balbuena (Texas A&M University) 2-214

Presentation Number: bat450 Presentation Title: Design, Processing, and Integration of Pouch-Format Cell for High-Energy Lithium-Sulfur Batteries Principal Investigator: Mei Cai (General Motors) 2-218

Presentation Number: bat451 Presentation Title: Solvent-Free and Non-Sintered 500 Wh/kg All Solid-State Battery Principal Investigator: Mike Wixom (Navitas Advanced Solutions Group). 2-221

Presentation Number: bat452 Presentation Title: High-Energy Solid-State Lithium Batteries with Organic Cathode Materials Principal Investigator: Yan Yao (University of Houston) .. 2-224

Presentation Number: bat453 Presentation Title: Composite Cathode Architectures Made by Freeze-Casting for All Solid-State Lithium Batteries Principal Investigator: Marca Doeff (Lawrence Berkeley National Laboratory) 2-228

Presentation Number: bat454 Presentation Title: Development of Long-Life Lithium/Sulfur-Containing Polyacrylonitrile Cells Principal Investigator: Ping Liu (University of California at San Diego) 2-231

Presentation Number: bat455 Presentation Title: In Operando Characterization of Lithium Plating and Stripping Principal Investigator: William Chueh (Stanford University) 2-235

Acronyms and Abbreviations 2-238

3. Energy Efficient Mobility Systems 3-1

Project Feedback 3-2

Presentation Number: eems007 Presentation Title: Mobility Data and Models Informing Smart Cities Principal Investigator: Joshua Sperling (National Renewable Energy Laboratory) 3-7

Presentation Number: eems009 Presentation Title: Modeling and Simulation of Automated Mobility Districts Principal Investigator: Venu Garikapati (National Renewable Energy Laboratory) 3-9

Presentation Number: eems011 Presentation Title: Integrated Mesoscale Urban Systems Modeling with Behavior, Energy, Autonomy, and Mobility (BEAM) to Explore Shared and Automated Vehicles and their Impacts on Energy and Mobility Principal Investigator: Zac Needell (Lawrence Berkeley National Laboratory) 3-12

Presentation Number: eems013 Presentation Title: ANL Core Tools—Simulation Principal Investigator: Aymeric Rousseau (Argonne National Laboratory) 3-15

Presentation Number: eems016 Presentation Title: Energy-Efficient CAVs Principal Investigator: Dominik Karbowski (Argonne National Laboratory) 3-18

Presentation Number: eems019 Presentation Title: Smart Urban Signal Infrastructure and Control Principal Investigator: Hong Wang (Oak Ridge National Laboratory)....................3-21

Presentation Number: eems020 Presentation Title: Multi-Scenario Assessment of Optimization Opportunities due to Connectivity and Automation Principal Investigator: Jackeline Rios-Torres (Oak Ridge National Laboratory)....................3-23

Presentation Number: eems023 Presentation Title: The Whole Traveler Transportation-Behavior Study Principal Investigator: Anna Spurlock (Lawrence Berkeley National Laboratory)........3-26

Presentation Number: eems027 Presentation Title: Multi-Modal Energy Analysis for Freight Principal Investigator: Alicia Birky (National Renewable Energy Laboratory) 3-29

Presentation Number: eems028 Presentation Title: Developing an Eco-Cooperative Automated Control System (Eco-CAC) Principal Investigator: Hesham Rakha (Virginia Tech University) 3-32

Presentation Number: eems030 Presentation Title: Experimental Evaluation of Eco-Driving Strategies Principal Investigator: Wei Zhang-Bin (Lawrence Berkeley National Laboratory).3-35

Presentation Number: eems031 Presentation Title: Traffic Micro-Simulation of Energy Impacts of CAV Concepts at Various Market Penetrations Principal Investigator: Hao Liu (Lawrence Berkeley National Laboratory)....................3-38

Presentation Number: eems033 Presentation Title: Using Passenger Car Cooperative Adaptive Cruise Control (CACC) to Test Operational Energy Consumption at Intersection with Active Traffic Signal Control Principal Investigator: Xiao Lu-Yun (Lawrence Berkeley National Laboratory)....................3-41

Presentation Number: eems034 Presentation Title: Optimization of Intra-City Freight Movement and New Delivery Methods Principal Investigator: Amy Moore (Oak Ridge National Laboratory)....................3-44

Presentation Number: eems035 Presentation Title: Coupling Land-Use Models and Network-Flow Models Principal Investigator: Paul Wadell (University of California at Berkeley)........3-47

Presentation Number: eems037 Presentation Title: High-Performance Computing (HPC) and Big Data Solutions for Mobility Design and Planning Principal Investigator: Jane Macfarlane (Lawrence Berkeley National Laboratory)....................3-50

Presentation Number: eems038 Presentation Title: Charging and Repositioning Decision Making for Fully Automated Ride-Hailing Fleet Principal Investigator: Zonggen Yi (Idaho National Laboratory)....................3-52

Presentation Number: eems039 Presentation Title: Charging Infrastructure Design Tradeoffs for a Fleet of Human-Driven and Fully Automated Electric Vehicles in San Francisco Principal Investigator: John Smart (Idaho National Laboratory)....................3-55

Presentation Number: eems040 Presentation Title: Dynamic Wireless Power Transfer Feasibility Principal Investigator: Omer Onar (Oak Ridge National Laboratory) 3-58

Presentation Number: eems041 Presentation Title: ANL Core Tools—Hardware Principal Investigator: Kevin Stutenberg (Argonne National Laboratory)....................3-60

Presentation Number: eems044 Presentation Title: Quantification of National Energy Impacts of Electrified Shared Mobility with Infrastructure Support Principal Investigator: Joann Zhou (Argonne National Laboratory)....................3-63

Presentation Number: eems045 Presentation Title: Focused Validation and Data Collection to SMART Activities Principal Investigator: Eric Rask (Argonne National Laboratory)............3-65

Presentation Number: eems057 Presentation Title: Urban Traveler–Changes and Impacts: Mobility Energy Productivity (MEP) Metric Principal Investigator: Venu Garikapati (National Renewable Energy Laboratory)..3-67

Presentation Number: eems058 Presentation Title: Systems and Modeling for Accelerated Research in Transportation (SMART) Mobility Consortium Tools and Process Development Principal Investigator: Aymeric Rousseau (Argonne National Laboratory) 3-70

Presentation Number: eems059 Presentation Title: Experimental Evaluation of CACC for Passenger Cars Principal Investigator: Xiao Lu-Yun (Lawrence Berkeley National Laboratory) 3-72

Presentation Number: eems060 Presentation Title: Agent-Based Model and Data Collection for Inter- and Intracity Freight Movement Principal Investigator: Monique Stinson (Argonne National Laboratory) 3-75

Presentation Number: eems061 Presentation Title: Real-Time Data and Simulation for Optimizing Regional Mobility in the United States Principal Investigator: Jibonananda Sanyal (Oak Ridge National Laboratory)...3-77

Presentation Number: eems062 Presentation Title: Deep-Learning for Connected and Automated Vehicle (CAV) Development Principal Investigator: Robert Patton (Oak Ridge National Laboratory)..3-80

Presentation Number: eems063 Presentation Title: Ubiquitous Traffic Volume Estimation through Machine-Learning Procedure Principal Investigator: Venu Garikapati (National Renewable Energy Laboratory)..3-83

Presentation Number: eems066 Presentation Title: Livewire Data Platform--A Solution for Energy Efficient Mobility Systems (EEMS) Data Sharing Principal Investigator: Lauren Spath Luhring (National Renewable Energy Laboratory)...3-86

Presentation Number: eems067 Presentation Title: Virtual and Physical Proving Ground for Development and Validation of Future Mobility Technologies Principal Investigator: Dean Deter (Oak Ridge National Laboratory)...3-91

Presentation Number: eems069 Presentation Title: Next-Generation Intelligent Traffic Signal for Multimodal, Shared, and Automated Future Principal Investigator: Andrew Powch (Xtelligent)3-94

Presentation Number: eems072 Presentation Title: Charging Infrastructure Needs for Electrification of Freight Delivery Vehicles Principal Investigator: Victor Walker (Idaho National Laboratory) 3-97

Presentation Number: eems074 Presentation Title: Smart Cities Topology–Curbs and Parking Principal Investigator: Stanley Young (National Renewable Energy Laboratory) 3-101

Presentation Number: eems078 Presentation Title: Simulation Model Results for Energy and Mobility Impact of Behavioral Scenarios in POLARIS Principal Investigator: Joshua Auld (Argonne National Laboratory)...3-104

Presentation Number: eems079 Presentation Title: Travel-Time Use and Value With Mobility Services Principal Investigator: Paul Leiby (Oak Ridge National Laboratory) 3-108

Presentation Number: eems081 Presentation Title: Nationwide Energy and Mobility Impacts of CAV Technologies Principal Investigator: David Gohlke (Argonne National Laboratory) ...3-111

Presentation Number: eems082 Presentation Title: Validation of Connected and Automated Mobility System Modeling and Simulation Principal Investigator: Jeffrey Rupp (American Center for Mobility)....3-114

Presentation Number: eems083 Presentation Title: CIRCLES: Congestion Impact Reduction via CAV-in-the-loop Lagrangian Energy Smoothing Principal Investigator: Alexandre Bayen (University of California at Berkeley)....3-117

Presentation Number: eems084 Presentation Title: Energy-Efficient Maneuvering of connected and Automated Vehicles (CAVs) with Situational Awareness at Intersections Principal Investigator: Sankar Rengarajan (Southwest Research Institute)....3-120

Presentation Number: eems086 Presentation Title: Simulation Tool for Energy-Efficient Connected and Automated Vehicle (CAV) Control Development Principal Investigator: Dominik Karbowski (Argonne National Laboratory)....3-124

Presentation Number: eems087 Presentation Title: Computation of Metropolitan-Scale, Quasi-Static Traffic Assignment Models Using High-Performance Computing Principal Investigator: Jane Macfarlane (Lawrence Berkeley National Laboratory)....3-126

Presentation Number: eems088 Presentation Title: Chicago Transit Authority Transit Network Efficiency and the Changing Mobility Landscape Principal Investigator: Joshua Auld (Argonne National Laboratory)....3-128

Acronyms and Abbreviations....3-132

4. Electrification....4-1

Project Feedback....4-2

Presentation Number: elt089 Presentation Title: Assessing the North American Supply Chain for Traction-Drive Inverters, Motors, and Batteries for Class 3-8 Hybrid Electric and Plug-In Electric Commercial Vehicles Principal Investigator: Chris Whaling (Synthesis Partners)....4-10

Presentation Number: elt091 Presentation Title: Cost-Effective 6.5% Silicon Steel Laminate for Electric Machines Principal Investigator: Jun Cui (Iowa State University)....4-13

Presentation Number: elt115 Presentation Title: Zero-Emission Cargo Transport I: Zero Emission Drayage Trucks Principal Investigator: Phil Barroca (South Coast Air Quality Management District)....4-17

Presentation Number: elt158 Presentation Title: Zero-Emission Cargo Transport II: San Pedro Bay Ports Hybrid & Fuel-Cell Electric Vehicle Project Principal Investigator: Seungbum Ha (South Coast Air Quality Management District)....4-19

Presentation Number: elt187 Presentation Title: Comprehensive Assessment of On- and Off-Board, Vehicle-to-Grid Technology Performance and Impacts on Batteries and the Grid (SPIN System) Principal Investigator: Sunil Chhaya (Electric Power Research Institute)....4-21

Presentation Number: elt188 Presentation Title: Bi-Directional Wireless Power Flow for Medium-Duty, Vehicle-to-Grid Connectivity Principal Investigator: Steven Sokolsky (CALSTART)....4-25

Presentation Number: elt189 Presentation Title: Electric Truck with Range-Extending Engine (ETREE) Principal Investigator: Jesse Dalton (Cummins-Peterbilt)....4-27

Presentation Number: elt190 Presentation Title: Medium-Duty Urban Range Extended Connected Powertrain (MURECP) Principal Investigator: Matthew Thorington (Bosch)....4-31

Presentation Number: elt191 Presentation Title: Medium-Duty Vehicle Powertrain Electrification and Demonstration Principal Investigator: Wiley McCoy (McLaren)....4-34

Presentation Number: elt197 Presentation Title: High Power and Dynamic Wireless Charging of Electric Vehicles Principal Investigator: Veda Galigekere (Oak Ridge National Laboratory) 4-38

Presentation Number: elt198 Presentation Title: Cybersecurity: Securing Vehicle Charging Infrastructure Principal Investigator: Jay Johnson (Sandia National Laboratories) 4-41

Presentation Number: elt199 Presentation Title: Cybersecurity: Consequence-Driven Cybersecurity for High-Power Charging Infrastructure Principal Investigator: Richard Carlson (Idaho National Laboratory) 4-48

Presentation Number: elt200 Presentation Title: Scalable Electric Vehicle Smart Charging Using Collaborative Autonomy Principal Investigator: Steve Chapin (Lawrence Livermore National Laboratory) 4-53

Presentation Number: elt201 Presentation Title: Charging Infrastructure Technologies: Smart Vehicle-Grid Integration--ANL Principal Investigator: Keith Hardy (Argonne National Laboratory) 4-57

Presentation Number: elt202 Presentation Title: Charging Infrastructure Technologies: Smart Electric Vehicle Charging for a Reliable and Resilient Grid (RECHARGE) Principal Investigator: Andrew Meintz (National Renewable Energy Laboratory).................................4-60

Presentation Number: elt204 Presentation Title: Charging Infrastructure Technologies: Development of a Multiport, >1 MW Charging System for Medium- and Heavy-Duty Electric Vehicles Principal Investigator: Andrew Meintz (National Renewable Energy Laboratory) ..4-64

Presentation Number: elt205 Presentation Title: Cybersecurity for Grid-Connected Extreme Fast Charging Station (CyberX) Principal Investigator: David Coats (ABB) 4-68

Presentation Number: elt206 Presentation Title: Cybersecurity Platform and Certification Framework Development for Extreme Fast Charging, Integrated Charging, Infrastructure Ecosystem Principal Investigator: Sunil Chhaya (Electric Power Research Institute)............4-70

Presentation Number: elt207 Presentation Title: Enabling Secure and Resilient Extreme Fast Charging: A Software/Hardware Security Co-Design Approach Principal Investigator: Ryan Gerdes (Virginia Tech University) 4-74

Presentation Number: elt208 Presentation Title: Highly Integrated Power Module Principal Investigator: Emre Gurpinar (Oak Ridge National Laboratory)...4-77

Presentation Number: elt209 Presentation Title: High-Voltage, High-Power Density Traction-Drive Inverter Principal Investigator: Gui Su-Jia (Oak Ridge National Laboratory)..............4-81

Presentation Number: elt210 Presentation Title: Development of Next-Generation Vertical Gallium-Nitride Devices for High-Power Density Electric Drivetrain Principal Investigator: Greg Pickrell (Sandia National Laboratories) 4-84

Presentation Number: elt211 Presentation Title: Power Electronics Thermal Management Principal Investigator: Gilbert Moreno (National Renewable Energy Laboratory) 4-89

Presentation Number: elt212 Presentation Title: Non-Heavy Rare-Earth High-Speed Motors Principal Investigator: Tsarafidy Raminosoa (Oak Ridge National Laboratory) 4-93

Presentation Number: elt213 Presentation Title: High-Fidelity Multiphysics Material Models for Electric Motors Principal Investigator: Jason Pries (Oak Ridge National Laboratory).............4-96

Presentation Number: elt214 Presentation Title: Electric Motor Thermal Management Principal Investigator: Kevin Bennion (National Renewable Energy Laboratory) 4-100

Presentation Number: elt215 Presentation Title: Permanent Magnets without Critical Rare Earths to Enable Electric Drive Motors with Exceptional Power Density Principal Investigator: Iver Anderson (Ames Laboratory)..4-103

Presentation Number: elt216 Presentation Title: Isotropic, Bottom-Up Soft Magnetic Composites for Rotating Machines Principal Investigator: Todd Monson (Sandia National Laboratories).....4-107

Presentation Number: elt217 Presentation Title: Integrated/Traction Drive Thermal Management Principal Investigator: Bidzina Kekelia (National Renewable Energy Laboratory)...............4-111

Presentation Number: elt218 Presentation Title: Advanced Power Electronics Designs--Reliability and Prognostics Principal Investigator: Doug DeVoto (National Renewable Energy Laboratory)........4-114

Presentation Number: elt219 Presentation Title: Power Electronics Materials and Bonded Interfaces--Reliability and Lifetime Principal Investigator: Paul Paret (National Renewable Energy Laboratory)........4-117

Presentation Number: elt221 Presentation Title: Integrated Electric Drive System Principal Investigator: Shajjad Chowdhury (Oak Ridge National Laboratory)........4-120

Presentation Number: elt222 Presentation Title: High-Reliability Ceramic Capacitors to Enable Extreme Power Density Improvements Principal Investigator: Jack Flicker (Sandia National Laboratories)........4-122

Presentation Number: elt223 Presentation Title: Component Testing, Co-Optimization, and Trade-Space Evaluation Principal Investigator: Jason Neely (Sandia National Laboratories)4-125

Presentation Number: elt234 Presentation Title: Soft Magnets to Achieve High-Efficiency Electric-Drive Motors of Exceptional Power Density Principal Investigator: Matthew Kramer (Ames Laboratory)........4-127

Presentation Number: elt236 Presentation Title: Direct-Current Conversion Equipment Connected to the Medium-Voltage Grid for Extreme Fast Charging Utilizing Modular and Interoperable Architecture Principal Investigator: Watson Collins (Electric Power Research Institute)........4-131

Presentation Number: elt237 Presentation Title: Enabling Extreme Fast Charging with Energy Storage Principal Investigator: Jonathan Kimball (Missouri S&T)........4-133

Presentation Number: elt238 Presentation Title: Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State Direct-Current Protection Principal Investigator: Srdjan Lukic (North Carolina State University)........4-135

Presentation Number: elt239 Presentation Title: High-Power Inductive Charging System Development and Integration for Mobility Principal Investigator: Omer Onar (Oak Ridge National Laboratory)........4-137

Presentation Number: elt240 Presentation Title: Wireless Extreme Fast Charging for Electric Trucks (WXFC-Trucks) Principal Investigator: Mike Masquelier (WAVE)........4-140

Presentation Number: elt241 Presentation Title: High-Efficiency, Medium-Voltage Input, Solid-State, Transformer-Based 400-kW/1000-V/400-A Extreme Fast Charger for Electric Vehicles Principal Investigator: Charles Zhu (Delta Electronics)........4-143

Presentation Number: elt242 Presentation Title: Heterogeneous Integration Technologies for High-Temperature, High-Density, Low-Profile Power Modules of Wide Bandgap Devices in Electric-Drive Applications Principal Investigator: G.Q. Lu (Virginia Tech)........4-147

Presentation Number: elt243 Presentation Title: Integrated Motor and Drive for Traction Applications Principal Investigator: Bulent Sarlioglu (University of Wisconsin)........4-149

Presentation Number: elt244 Presentation Title: Next-Generation, High-Temperature, High-Frequency, High-Efficiency, High-Power Density Traction System Principal Investigator: Robert Pilawa (University of California at Berkeley) 4-151

Presentation Number: elt245 Presentation Title: Integration Methods for High-Density Integrated Electric Drives Principal Investigator: Alan Mantooth (University of Arkansas) 4-154

Presentation Number: elt246 Presentation Title: Implementation of Wide-Bandgap Devices in Circuits, Circuit Topology, System Integration as well as Silicon Carbide Devices Principal Investigator: Anant Agarwal (Ohio State University) 4-157

Presentation Number: elt247 Presentation Title: Cost-Competitive, High-Performance, Highly Reliable Power Devices on Silicon Carbide and Gallium Nitride Principal Investigator: Woongje Sung (State University of New York Polytechnic Institute) 4-159

Presentation Number: elt248 Presentation Title: Multi-Objective Design Optimization of 100-kW Non-Rare-Earth or Reduced-Rare Earth Machines Principal Investigator: Scott Sudhoff (Purdue University) 4-162

Presentation Number: elt249 Presentation Title: Rugged Wide Bandgap Devices and Advanced Electric Machines for High-Power Density Automotive Electric Drives Principal Investigator: Victor Veliadis (North Carolina State University) 4-164

Presentation Number: elt250 Presentation Title: Design, Optimization, and Control of a 100-kW Electric Traction Motor Meeting or Exceeding DOE 2025 Targets Principal Investigator: Ian Brown (Illinois Institute of Technology) 4-166

Presentation Number: elt251 Presentation Title: Device- and System-Level Thermal Packaging for Electric-Drive Technologies Principal Investigator: Yogendra Joshi (Georgia Institute of Technology) 4-168

Presentation Number: elt252 Presentation Title: Wound-Field Synchronous Machine-System Integration toward Increased Power Density and Commercialization Principal Investigator: Lakshmi Iyer (Magma Services of America, Inc.) 4-170

Presentation Number: elt253 Presentation Title: Motor with Advanced Concepts for High-Power Density and Integrated Cooling for Efficiency Machine Principal Investigator: Jagadeesh Tangudu (United Technologies Research Center) 4-172

Presentation Number: elt254 Presentation Title: Ultra-High Speed, High-Temperature Motor Principal Investigator: Joseph Lyding (University of Illinois at Urbana-Champaign) 4-175

Presentation Number: elt255 Presentation Title: Cost-Effective, Rare-Earth-Free, Flux-Doubling, Torque-Doubling, Increased Power Density Traction Motor with Near-Zero Open-Circuit Back-Electromagnetic Field and No-Cogging Torque Principal Investigator: Soma Essakiappan (University of North Carolina at Charlotte) 4-179

Presentation Number: elt256 Presentation Title: Amorphous Metal Ribbons and Metal Amorphous Nanocomposite Materials Enabled High-Power Density Vehicle Motor Applications Principal Investigator: Mike McHenry (Carnegie Mellon University) 4-182

Presentation Number: elt257 Presentation Title: Directed Electric Charging of Transportation using eXtreme Fast Charging (XFC) (DIRECT XFC) Principal Investigator: Tim Pennington (Idaho National Laboratory) 4-185

Presentation Number: elt258 Presentation Title: Grid-Enhanced, Mobility-Integrated Network Infrastructures for Extreme Fast Charging (GEMINI-XFC) Principal Investigator: Matteo Muratori (National Renewable Energy Laboratory) 4-189

Presentation Number: elt259 Presentation Title: Development and Commercialization of Heavy-Duty Battery Electric Trucks Under Diverse Climate Conditions Principal Investigator: Marcus Malinosky (Daimler Trucks North America) 4-193

Presentation Number: elt260 Presentation Title: Improving the Freight Productivity of a Heavy-Duty, Battery Electric Truck by Intelligent Energy Management Principal Investigator: Teresa Taylor (Volvo)..4-198

Presentation Number: elt261 Presentation Title: High-Efficiency Powertrain for Heavy-Duty Trucks using Silicon Carbide Inverter Principal Investigator: Ben Maruqart (Ricardo).........4-203

Presentation Number: elt262 Presentation Title: Long-Range, Heavy-Duty Battery-Electric Vehicle with Megawatt Wireless Charging Principal Investigator: Brian Lindgren (Kenworth) .4-207

Presentation Number: elt263 Presentation Title: Cybersecurity: Securing Vehicle Charging Infrastructure - Consequence Analysis and Threat Assessment Principal Investigator: Rick Pratt (Pacific Northwest National Laboratory) 4-212

Acronyms and Abbreviations 4-215

5. Fuel and Lubricant Technologies 5-1

Project Feedback 5-2

Presentation Number: ft037 Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima) Principal Investigator: Robert Wagner (Oak Ridge National Laboratory)..................5-4

Presentation Number: ft067 Presentation Title: Multi-Mode/Multi-Mode Compression Ignition: Fuel-Property Characterization and Prediction Principal Investigator: Tim Bays (Pacific Northwest National Laboratory)..5-10

Presentation Number: ft069 Presentation Title: Multi-Mode: Fuel-Property Impacts and Limitations on Combustion--Spark Ignition Focus Principal Investigator: Derek Splitter (Oak Ridge National Laboratory)...5-17

Presentation Number: ft070 Presentation Title: Multi-Mode: From In-Cylinder Combustion Diagnostics to Drive-Cycle Fuel Economy Principal Investigator: Magnus Sjoberg (Sandia National Laboratories)...5-23

Presentation Number: ft071 Presentation Title: Multi-Mode Operation in Gasoline Direct-Injection Engines: Fuel-Property Effects and Approaches to Expand the Advanced Compression-Ignition Range Principal Investigator: Toby Rockstroh (Argonne National Laboratory)........5-28

Presentation Number: ft072 Presentation Title: Multi-Mode: Desired Fuel Properties for Advanced Compression-Ignition and Spark-Ignition Engine Performance Principal Investigator: Chris Kolodziej (Argonne National Laboratory)...5-33

Presentation Number: ft073 Presentation Title: Co-Optima Emissions and Emissions Control for Spark Ignition and Advanced Compression Ignition Multi-Mode Combustion Principal Investigator: Sreshtha Sinha-Majumdar (Oak Ridge National Laboratory).............................5-38

Presentation Number: ft074 Presentation Title: Multi-Mode: Gasoline Direct-Injection Sprays Principal Investigator: Lyle Pickett (Sandia National Laboratories)..5-44

Presentation Number: ft075 Presentation Title: Multi-Mode: Fuel Kinetics Principal Investigator: Bill Pitz (Lawrence Livermore National Laboratory) 5-48

Presentation Number: ft076 Presentation Title: Model-Based Fuel and Engine Optimization Principal Investigator: Juliane Mueller (Lawrence Berkeley National Laboratory) 5-53

Presentation Number: ft077 Presentation Title: Heavy-Duty Mixed-Controlled Compression Ignition: Fuel Effects and Ducted Fuel Injection Principal Investigator: Charles Mueller (Sandia National Laboratories) 5-57

Presentation Number: ft078 Presentation Title: Heavy-Duty Mixed-Controlled Compression Ignition: Impacts of Fuel Properties on Combustion, Injection Characteristics, and Emissions Controls Principal Investigator: Martin Wissink (Oak Ridge National Laboratory) 5-60

Presentation Number: ft087 Presentation Title: Multimode, Co-Optimized, Light-Duty Vehicle Engine Principal Investigator: Phil Zoldak (Hyundai-Kia North America) 5-65

Presentation Number: ft088 Presentation Title: Fuel Property Experimental Kinetics Principal Investigator: Gina Fioroni (National Renewable Energy Laboratory) 5-69

Presentation Number: ft089 Presentation Title: Heavy-Duty Advanced Compression Ignition Principal Investigator: John Dec (Sandia National Laboratories) 5-73

Acronyms and Abbreviations 5-77

6. Materials Technologies 6-1

Project Feedback 6-2

Presentation Number: mat118 Presentation Title: Functionally Designed Ultra-Lightweight Carbon-Fiber Reinforced Thermoplastic Composites Door Assembly Principal Investigator: Srikanth Pilla (Clemson University) 6-8

Presentation Number: mat122 Presentation Title: Close-Proximity Electromagnetic Carbonization (CPEC) Principal Investigator: Felix Paulauskas (Oak Ridge National Laboratory) 6-12

Presentation Number: mat124 Presentation Title: Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber for Lightweight Vehicles Principal Investigator: Xiadong Li (University of Virginia) 6-16

Presentation Number: mat125 Presentation Title: Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber Principal Investigator: Jeramie Adams (Western Research Institute) 6-19

Presentation Number: mat126 Presentation Title: Room-Temperature Stamping of High-Strength Aluminum Alloys Principal Investigator: Aashish Rohatgi (Pacific Northwest National Laboratory) 6-22

Presentation Number: mat127 Presentation Title: U.S. Automotive Materials Partnership Low-Cost Magnesium Sheet Component Development and Demonstration Project Principal Investigator: Randy Gerken (Fiat Chrysler Automotive) 6-24

Presentation Number: mat136 Presentation Title: High-Performance Computing and High-Throughput Characterizations toward Interfaces-by-Design for Dissimilar Materials Joining Principal Investigator: Xin Sun (Oak Ridge National Laboratory) 6-28

Presentation Number: mat137 Presentation Title: Adhesive Bonding of Carbon-Reinforced Plastic to Advanced High-Strength Steel Principal Investigator: Zhili Feng (Oak Ridge National Laboratory) 6-31

Presentation Number: mat138 Presentation Title: Solid-State Joining of Magnesium Sheet to High-Strength Steel Principal Investigator: Piyush Upadhyay (Pacific Northwest National Laboratory) 6-35

Presentation Number: mat139 Presentation Title: Mechanical Joining of Thermoplastic Carbon-Fiber Reinforced Polymer to Die-Cast Magnesium Principal Investigator: Keerti Kappagantula (Pacific Northwest National Laboratory) 6-38

Presentation Number: mat142 Presentation Title: Metal-Matrix Composite Brakes Using Titanium Diboride Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory) 6-41

Presentation Number: mat146 Presentation Title: Ultra-Lightweight, Ductile Carbon-Fiber Reinforced Composites Principal Investigator: Vlastimil Kunc (Oak Ridge National Laboratory) 6-46

Presentation Number: mat147 Presentation Title: Continuous-Fiber, Malleable Thermoset Composites with Sub-1-Minute Dwell Times: Validation of Impact Performance and Evaluation of the Efficacy of the Compression Forming Process Principal Investigator: Philip Taynton (Mallinda, Inc.) 6-50

Presentation Number: mat149 Presentation Title: Non-Rare Earth Magnesium Bumper Beams Principal Investigator: Scott Whalen (Pacific Northwest National Laboratory) 6-51

Presentation Number: mat151 Presentation Title: Phase-Field Modeling of Corrosion for Design of Next-Generation Magnesium-Aluminum Vehicle Joints Principal Investigator: Adam Powell (Worcester Polytechnic Institute) 6-55

Presentation Number: mat152 Presentation Title: A Hybrid Physics-Based, Data-Driven Approach to Model Damage Accumulation in Corrosion of Polymeric Adhesives Principal Investigator: Roozbeh Dargazany (Michigan State University) 6-59

Presentation Number: mat153 Presentation Title: Multi-Scale Computational Platform for Predictive Modeling of Corrosion in Aluminum-Steel Joints Principal Investigator: Miki Banu (University of Michigan) 6-62

Presentation Number: mat162 Presentation Title: Machine Learning and Supercomputing to Predict Corrosion/Oxidation of High-Performance Valve Alloys Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory) 6-65

Presentation Number: mat163 Presentation Title: Multiscale Modeling of Corrosion and Oxidation Performance and Their Impact on High-Temperature Fatigue of Automotive Exhaust Manifold Components Principal Investigator: Mei Li (Ford) 6-69

Presentation Number: mat164 Presentation Title: Multiscale Development and Validation of the Stainless Steel Alloy Corrosion (SStAC) Tool for High-Temperature Engine Materials Principal Investigator: Michael Tonks (University of Florida) 6-73

Presentation Number: mat165 Presentation Title: Directly Extruded High Conductivity Copper for Electric Machines Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory) 6-78

Presentation Number: mat166 Presentation Title: Aluminum Purification and Magnesium Recovery from Magnesium-Aluminum Scrap Principal Investigator: John Hryn (Argonne National Laboratory) 6-81

Presentation Number: mat167 Presentation Title: Corrosion Mechanisms in Magnesium-Steel Dissimilar Joints Principal Investigator: Vineet Joshi (Pacific Northwest National Laboratory) 6-84

Presentation Number: mat168 Presentation Title: Low-Cost Resin Technology for the Rapid Manufacture of High-Performance Reinforced Composites Principal Investigator: Henry Sodano (Trimer Technologies, LLC) 6-87

Presentation Number: mat169 Presentation Title: Short-Fiber Preform Technology for Automotive Part Production Principal Investigator: Dirk Heider (Composites Automation, LLC) 6-91

Presentation Number: mat170 Presentation Title: Embedded Networked Elements for Resin Visualization and Evaluation (NERVE) System for Intelligent Manufacturing of Multifunctional Composites for Vehicles Principal Investigator: Amrita Kumar (Acellent Technologies, Inc.) ..6-94

Presentation Number: mat171 Presentation Title: Discontinuous Low-Cost Carbon Fiber/Bamboo Fiber Hybrid Intermediates for Lightweighting Vehicle Applications Principal Investigator: David Knight (Resource Fiber, LLC)..........6-97

Presentation Number: mat172 Presentation Title: High-Performance Fiber-Reinforced Vitrimer Composites through Compression Molding Principal Investigator: Yinghua Jin (NCO Technologies, LLC)..........6-99

Presentation Number: mat173 Presentation Title: Self-Sensing Fiber-Reinforced Composites Principal Investigator: Christopher Bowland (Oak Ridge National Laboratory)..........6-102

Presentation Number: mat174 Presentation Title: Carbon-Fiber Technology Facility (CFTF) Principal Investigator: Merlin Theodore (Oak Ridge National Laboratory)..........6-105

Presentation Number: mat175 Presentation Title: Novel Materials for Polymer Composite Engine Blocks Principal Investigator: Amit Naskar (Oak Ridge National Laboratory)..........6-108

Presentation Number: mat176 Presentation Title: Advanced Anticorrosion Coatings on Lightweight Magnesium Alloys by Atmospheric CO2 Plasma Treatment Principal Investigator: Gyoung Gug-Jang (Oak Ridge National Laboratory)..........6-112

Presentation Number: mat177 Presentation Title: Novel Aluminum Matrix Composite for Powertrain Applications Principal Investigator: Zhili Feng (Oak Ridge National Laboratory)...6-117

Presentation Number: mat179 Presentation Title: Development of High-Temperature Sample Environment for Advanced Alloy Characterization Utilizing High-Speed, Micron-Resolution X-Ray Imaging Techniques Principal Investigator: Dileep Singh (Argonne National Laboratory).6-123

Presentation Number: mat180 Presentation Title: Reducing The Weight of Vehicle Components via Lost-Foam Casting of Ductile and Austempered Ductile Iron Principal Investigator: Sarah Jordan (Skuld)..........6-127

Presentation Number: mat182 Presentation Title: High-Strength Aluminum-Graphene Composite for Powertrain System Principal Investigator: Xiao Li (Pacific Northwest National Laboratory)..........6-130

Presentation Number: mat183 Presentation Title: High-Temperature Coatings for Valve Alloys Principal Investigator: Sebastien Dryepondt (Oak Ridge National Laboratory)..........6-133

Presentation Number: mat184 Presentation Title: Development of Cast, Higher Temperature Austenitic Alloys Principal Investigator: Yuki Yamamoto, Michael P. Brady (Oak Ridge National Laboratory)..........6-137

Presentation Number: mat185 Presentation Title: Additively Manufactured Interpenetrating Composites (AMIPC) via Hybrid Manufacturing Principal Investigator: Derek Splitter (Oak Ridge National Laboratory)..........6-142

Presentation Number: mat186 Presentation Title: Modeling of Light-Duty Engines Principal Investigator: Charles Finney (Oak Ridge National Laboratory)..........6-148

Presentation Number: mat187 Presentation Title: Fundamental Studies of Complex Precipitation Pathways in Lightweight Alloys Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)..........6-152

Presentation Number: mat188 Presentation Title: Properties of Cast Aluminum-Copper-Manganese-Zirconium Alloys Principal Investigator: Amit Shyam (Oak Ridge National Laboratory) 6-155

Presentation Number: mat189 Presentation Title: Fundamental Development of Aluminum Alloys for Additive Manufacturing Principal Investigator: Alex Plotkowski (Oak Ridge National Laboratory) 6-157

Presentation Number: mat190 Presentation Title: Oxidation Resistant Valve Alloys Principal Investigator: G Muralidharan (Oak Ridge National Laboratory) 6-160

Presentation Number: mat191 Presentation Title: Overview of Advanced Characterization within the Powertrain Materials Core Program Principal Investigator: Tom Watkins (Oak Ridge National Laboratory) 6-163

Presentation Number: mat192 Presentation Title: Fundamentals of Austenitic Alloys via Additive Manufacturing Principal Investigator: Sebastien Dryepondt (Oak Ridge National Laboratory) 6-167

Presentation Number: mat193 Presentation Title: Higher Temperature Heavy-Duty Piston Alloys Principal Investigator: Dean Pierce (Oak Ridge National Laboratory) 6-171

Presentation Number: mat194 Presentation Title: Accelerated Design of Alumina-Forming, High Temperature Austenitic Alloys Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory) 6-175

Acronyms and Abbreviations 6-179

7. Technology Integration 7-1

Project Feedback 7-2

Presentation Number: ti091 Presentation Title: Solutions for Curbside-Charging Electric Vehicles Planned for Urban Growth Principal Investigator: Robert Cox (University of North Carolina at Charlotte) 7-5

Presentation Number: ti092 Presentation Title: Vehicle Charging Innovations for Multi-Unit Dwellings (VCI-MUD) Principal Investigator: Kevin Wood (Center for Sustainable Energy) .7-9

Presentation Number: ti093 Presentation Title: Electric Vehicle Supply Equipment (EVSE) Innovation: Streetlight Charging in City Right-Of-Way Principal Investigator: Miriam Bouallegue (Metropolitan Energy Center) 7-13

Presentation Number: ti094 Presentation Title: Advanced Transportation Hub Efficiency using Novel Analysis (ATHENA) Principal Investigator: Caleb Phillips (National Renewable Energy Laboratory) 7-17

Presentation Number: ti095 Presentation Title: High-Performance Computing (HPC) for O'Hare Hub Principal Investigator: Aymeric Rousseau (Argonne National Laboratory) 7-21

Presentation Number: ti096 Presentation Title: Technology Integration to Gain Commercial Efficiency for the Urban Goods Delivery System Principal Investigator: Anne Goodchild (University of Washington) 7-25

Presentation Number: ti097 Presentation Title: Drones, Delivery Robots, Driverless Cars, and Intelligent Curbs for Increasing Energy Productivity of First-/Last-Mile Goods Movement Agreement Principal Investigator: Constantine Samaras (Carnegie Mellon University) 7-29

Presentation Number: ti098 Presentation Title: Transportation Energy Analytics Dashboard (TEAD) Principal Investigator: Michael Pack (University of Maryland) 7-33

Presentation Number: ti099 Presentation Title: Understanding and Improving Energy Efficiency of Regional Mobility Systems by Leveraging System-Level Data Principal Investigator: Zhen Qian (Carnegie Mellon University) 7-36

Presentation Number: ti100 Presentation Title: High-Dimensional, Data-Driven Energy Optimization for Multi-Modal Transit Agencies Principal Investigator: Philip Pugliese (Chattanooga Area Regional Transit Authority) 7-40

Presentation Number: ti101 Presentation Title: Mobility and Energy Improvements Realized through Prediction-Based Vehicle Powertrain Control and Traffic Management Principal Investigator: Thomas Bradley (Colorado State University) 7-43

Presentation Number: ti102 Presentation Title: Advancing Platooning with Advanced Driver-Assistance Systems Control Integration and Assessment Principal Investigator: Hoseinali Borhan (Cummins-Peterbilt) 7-46

Presentation Number: ti103 Presentation Title: Fuel-Efficient Platooning in Mixed Traffic Highway Environments Principal Investigator: Jeff Rupp (American Center for Mobility) ... 7-49

Presentation Number: ti104 Presentation Title: Using Real-Time Mass Transit in First-/Last-Mile Solution Principal Investigator: Andrea Broaddus (Ford) 7-53

Acronyms and Abbreviations 7-56

8. Vehicle Analysis 8-1

Project Feedback 8-2

Presentation Number: van016 Presentation Title: Transportation Data Program Principal Investigator: Stacy Davis (Oak Ridge National Laboratory) 8-3

Presentation Number: van017 Presentation Title: ANL VTO Analysis Modeling Program Principal Investigator: Michael Wang (Argonne National Laboratory) 8-10

Presentation Number: van018 Presentation Title: Light-Duty Vehicle Choice Modeling and Benefits Analysis Principal Investigator: Aaron Brooker (National Renewable Energy Laboratory) 8-17

Presentation Number: van023 Presentation Title: Assessing Energy and Cost Impact of Advanced Vehicle Technologies Principal Investigator: Aymeric Rousseau (Argonne National Laboratory) 8-24

Presentation Number: van032 Presentation Title: Tracking the Evolution of Electric Vehicles and New Mobility Technology Principal Investigator: Joann Zhou (Argonne National Laboratory) 8-31

Presentation Number: van033 Presentation Title: Transportation Macroeconomic Accounting Models: VISION and Non-Light Duty Energy and Greenhouse Gas (GHG) Emissions Accounting Tool (NEAT) Principal Investigator: Joann Zhou (Argonne National Laboratory) . 8-38

Acronyms and Abbreviations 8-44

9. Acronyms and Abbreviations 9-1

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Introduction

The 2020 U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy's (EERE) Vehicle Technologies Office (VTO) Annual Merit Review (AMR) was held June 1-4, 2020, virtually, due to extenuating circumstances resulting from the global Coronavirus (COVID-19) pandemic. The review encompassed work done by VTO: 292 individual activities were reviewed by 334 reviewers. Exactly 1,133 individual review responses were received for the VTO technical reviews.

The objective of the meeting was to review the accomplishments and plans for VTO over the previous 12 months, and provide an opportunity for industry, government, and academia to give inputs to DOE with a structured and formal methodology. The meeting also provided attendees with a virtual forum for interaction and technology information transfer.

The peer review process followed the guidelines of the Peer Review Guide developed by EERE. Each activity is reviewed every 3 years, at a minimum. However, VTO strives to have every activity reviewed every other year. The reviewers for the technical sessions were drawn from a wide variety of backgrounds, including current and former vehicle industry members, academia, government, and other expertise areas. Each reviewer was screened for conflicts of interest as prescribed by the Peer Review Guide.

Reviewers provided qualitative and quantitative feedback on VTO projects evaluated during the AMR. Qualitatively, reviewers offered written comments in response to a series of specific project evaluation questions. Quantitatively, reviewers provided numeric assessments for each of the same questions. These scores were organized and analyzed on both a project-level and subprogram-level basis. Tables summarizing the average numeric score for each question, by VTO subprogram portfolio, is presented below.

Table 1-1 – Average Project Scores, By VTO Research & Development Subprogram

VTO Subprogram	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Advanced Combustion Engines (ACE)	3.29	3.23	3.29	3.14	**3.24**
Battery Technologies R&D (BAT)	3.36	3.29	3.41	3.20	**3.31**
Energy Efficient Mobility Systems (EEMS)	3.30	3.31	3.34	3.17	**3.30**
Electrification (ELT)	3.19	3.16	3.17	3.08	**3.16**
Fuel and Lubricant Technologies (FT)	3.36	3.45	3.47	3.31	**3.41**
Materials Technologies (MAT)	3.29	3.31	3.30	3.14	**3.28**
Vehicle Analysis (VAN)	3.46	3.43	3.34	3.25	**3.40**

Table 1-2 – Average Project Scores, VTO Technology Integration Subprogram

VTO Subprogram	Objectives	Approach	Accomplish-ments	Collaboration	Overall Impact	Weighted Avg.
Technology Integration (TI)	3.33	3.37	3.27	3.50	3.25	**3.32**

Evaluation Criteria—Research & Development Subprogram Projects

In the technical research and development (R&D) subprogram sessions, reviewers were asked to respond to a series of specific questions regarding the breadth, depth, and appropriateness of the VTO R&D activities. The technical questions are listed below, along with appropriate scoring metrics. These questions were used for all formal VTO R&D project reviews.

Question 1. Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned. (Scoring weight for overall average = 20%)

- 4.0=Outstanding (sharply focused on critical barriers; difficult to improve approach significantly)
- 3.5=Excellent (effective; contributes to overcoming most barriers)
- 3.0=Good (generally effective but could be improved; contributes to overcoming some barriers)
- 2.5=Satisfactory (has some weaknesses; contributes to overcoming some barriers)
- 2.0=Fair (has significant weaknesses; may have some impact on overcoming barriers)
- 1.5=Poor (minimally responsive to project objectives; unlikely to contribute to overcoming the barriers)
- 1.0=Unsatisfactory (not responsive to project objectives; unlikely to contribute to overcoming the barriers).

Question 2. Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule. (Scoring weight for overall average = 40%)

- 4.0=Outstanding (sharply focused on critical barriers; difficult to improve significantly)
- 3.5=Excellent (effective; contributes to overcoming most barriers)
- 3.0=Good (generally effective but could be improved; contributes to overcoming some barriers)
- 2.5=Satisfactory (has some weaknesses; contributes to overcoming some barriers)
- 2.0=Fair (has significant weaknesses; may have some impact on overcoming barriers)

- 1.5=Poor (minimally responsive to project objectives; unlikely to contribute to overcoming the barriers)
- 1.0=Unsatisfactory (not responsive to project objectives; unlikely to contribute to overcoming the barriers).

Question 3. Collaboration and Coordination Across Project Team. (Scoring weight for overall average = 10%)

- 4.0=Outstanding (close, appropriate collaboration with other institutions; partners are full participants and well-coordinated)
- 3.5=Excellent (good collaboration; partners participate and are well-coordinated)
- 3.0=Good (collaboration exists; partners are fairly well-coordinated)
- 2.5=Satisfactory (some collaboration exists; coordination between partners could be significantly improved)
- 2.0=Fair (a little collaboration exists; coordination between partners could be significantly improved)
- 1.5=Poor (most work is done at the sponsoring organization with little outside collaboration; little or no apparent coordination with partners)
- 1.0=Unsatisfactory (no apparent coordination with partners).

Question 4. Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended. (Scoring weight for overall average = 10%)

- 4.0=Outstanding (sharply focused on critical barriers; difficult to improve significantly)
- 3.5=Excellent (effective; contributes to overcoming most barriers)
- 3.0=Good (generally effective but could be improved; contributes to overcoming some barriers)
- 2.5=Satisfactory (has some weaknesses; contributes to overcoming some barriers)
- 2.0=Fair (has significant weaknesses; may have some impact on overcoming barriers)
- 1.5=Poor (minimally responsive to project objectives; unlikely to contribute to overcoming the barriers)
- 1.0=Unsatisfactory (not responsive to project objectives; unlikely to contribute to overcoming the barriers)
- N/A=Not Applicable (project has ended).

Question 5. Relevance—Does this project support the overall DOE objectives? Why or why not? (Scoring weight, not included with overall average = 20%)

- Yes
- No.

Question 6. Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

- Excessive
- Sufficient
- Insufficient.

Evaluation Criteria—Technology Integration Projects

Reviewers for the Technology Integration (TI) technical session answered questions tailored to TI's 2020 AMR focus on increasing transportation efficiency and fuel diversity. These technical questions are listed below, along with appropriate scoring metrics.

Question 1. Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency. (Scoring weight for overall average = 20%)

- 4.0=Outstanding (project objectives are sharply focused on supporting DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency. The project has a direct and substantial impact upon addressing barriers; difficult to improve project objectives significantly)
- 3.5=Excellent (project objectives are effective and substantially support DOE/VTO objectives; project addresses a significant number of barriers; effectively contributes to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency)
- 3.0=Good (project objectives are generally effective and support DOE/VTO objectives, but could be improved; project addresses some barriers; contributes to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency)
- 2.5=Satisfactory (project objectives have some weaknesses and support DOE/VTO objectives; project addresses some barriers; project may have some impact contributing to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency)
- 2.0=Fair (project objectives have significant weaknesses and minimally support DOE/VTO objectives; project addresses few barriers; project may have a small impact contributing to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency)
- 1.5=Poor (project objectives are minimally responsive to DOE/VTO objectives; project does not address barriers; project is unlikely to contribute to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency)
- 1.0=Unsatisfactory (project objectives are not responsive to DOE/VTO objectives; project fails to address any barriers; project is highly unlikely to contribute to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency).

Question 2. Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts. (Scoring weight for overall average = 20%)

- 4.0=Outstanding (project approach is sharply focused on achieving project objectives; difficult to improve project approach significantly)
- 3.5=Excellent (effective; project approach contributes to achieving the majority of project objectives)
- 3.0=Good (generally effective but project approach could be improved; contributes to achieving some of the project objectives)
- 2.5=Satisfactory (has some weaknesses; project approach contributes to achieving some project objectives)
- 2.0=Fair (has significant weaknesses; project approach may have some impact on achieving project objectives)
- 1.5=Poor (minimally responsive to project objectives; project approach is unlikely to contribute to achieving project objectives)
- 1.0=Unsatisfactory (not responsive to project objectives; project approach is highly unlikely to contribute to achieving project objectives).

Question 3. Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals. (Scoring weight for overall average = 40%)

- 4.0=Outstanding (project demonstrates significant accomplishments; strong progress toward achieving both project and DOE objectives; difficult to improve progress significantly)
- 3.5=Excellent (project demonstrates many accomplishments; very effective progress toward achieving overall project objectives and DOE goals)
- 3.0=Good (project accomplishments are generally effective; progress is on schedule to contribute to some project objectives and DOE goals)
- 2.5=Satisfactory (project has some accomplishments, but also displays some weaknesses; progress could be improved; contributes to some project objectives and DOE goals)
- 2.0=Fair (project has few accomplishments and demonstrates significant weaknesses; rate of progress is slow; minimal contribution to project objectives or DOE goals)
- 1.5=Poor (minimal demonstration of accomplishments; progress is significantly behind schedule; unlikely to contribute to project objectives or DOE goals)
- 1.0=Unsatisfactory (project demonstrates no accomplishments; limited or no demonstrated progress; not responsive to project objectives).

Question 4. Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners. (Scoring weight for overall average = 10%)

- 4.0=Outstanding (sharply focused on collaboration among project team members; team is well-suited to effectively carry out the work of the project and have strong working relationships; no notable weaknesses)
- 3.5=Excellent (effective; team members meaningfully contribute to carrying out the work of the project, are well-suited to perform the work and have excellent working relationships)
- 3.0=Good (generally effective but could be improved; collaboration exists; team members are fairly well-suited to project work and have good working relationships)
- 2.5=Satisfactory (has some weaknesses; collaboration among team members is satisfactory for carrying out the work of the project; project partnerships, team members and working relationships could be improved)
- 2.0=Fair (has significant weaknesses; little collaboration exists and team could be improved)
- 1.5=Poor (minimally responsive; little collaboration exists and team lacks effective working relationships)
- 1.0=Unsatisfactory (little or no apparent collaboration between team members; project team is lacking critical expertise to effectively carry out the work of the project).

Question 5. Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency. (Scoring Weight for overall average = 10%).

- 4.0=Outstanding (sharply focused on critical barriers to achieving project objectives; difficult to improve significantly)
- 3.5=Excellent (effective; contributes to overcoming most barriers to achieving project objectives)
- 3.0=Good (generally effective in overcoming barriers to achieving project objectives)
- 2.5=Satisfactory (has some weaknesses; but needs better focus on overcoming some barriers to achieve project objectives)
- 2.0=Fair (has significant weaknesses)
- 1.5=Poor (minimally responsive)
- 1.0=Unsatisfactory (not responsive to eliminating barriers to achieving project objectives).

Question 6. Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

- Yes
- Maybe

- No.

Project Scoring

R&D Subprogram Projects

For R&D subprogram sessions, reviewers were asked to provide numeric scores (on a scale of 1.0-4.0 in one-half point increments, as indicated above) for Question 1 through Question 4 of each formally reviewed activity. For each reviewed project, the individual reviewer scores for Question 1 through Question 4 were averaged to provide information on the project's question-by-question scoring. Scores for each of these four criteria were weighted using the formula below to create a Weighted Average for each project. This allows a project's question-by-question and final overall scores to be meaningfully compared against another project:

Weighted Average = [Question 1 Score x 0.20] + [Question 2 Score x 0.40] +

[Question 3 Score x 0.10] + [Question 4 Score x 0.10]

Each reviewed activity has a corresponding bar chart representing that project's average scores for each of the four designated criteria. As demonstrated in Figure 1, a bullet and error line are included within the green bars representing the corresponding average and standard deviation of criteria scores for all of the reviewed projects in the same subprogram.

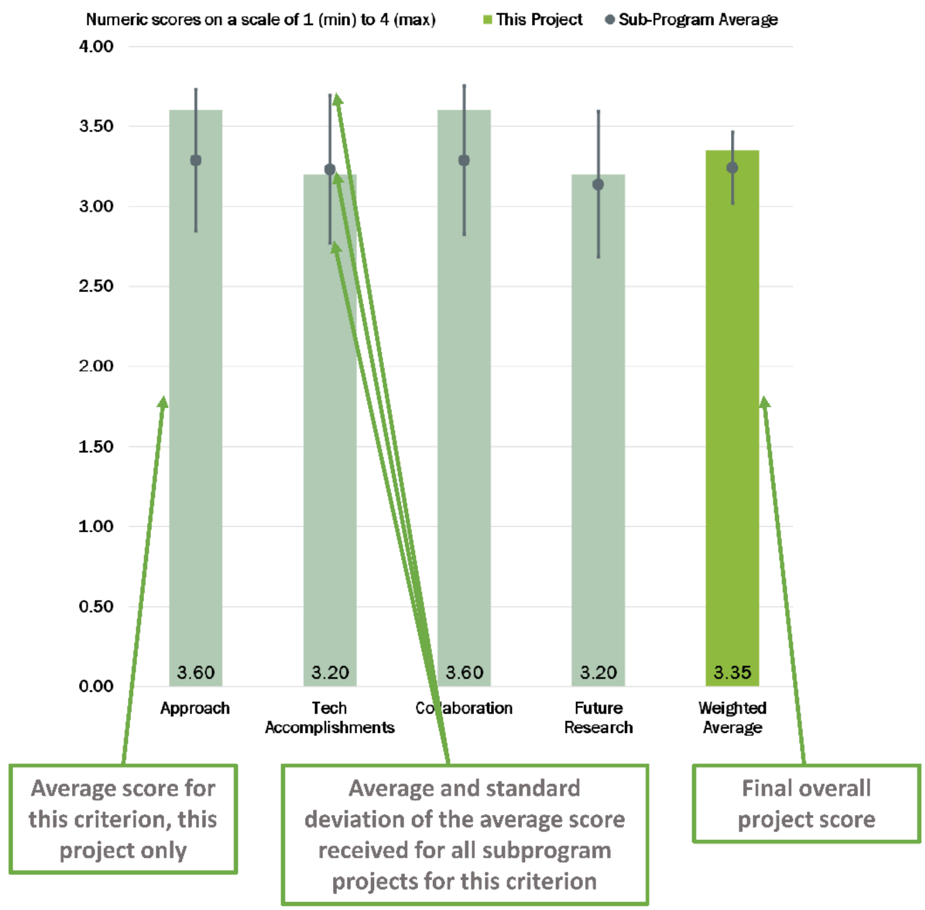

Figure 1. Sample Question 1 through Question 4 score averages, standard deviations, and Overall Weighted Average for an R&D project.

Reviewers were also asked to evaluate a given project's relevance and funding through Question 5 and Question 6, which were each scored on a different scale than Question 1 through Question 4. For the R&D subprogram sessions, while Question 1 through Question 4 were rated on a 1.0 to 4.0 scale in one-half point increments, Question 5 was rated on a yes or no scale, and Question 6 was rated on an excessive, sufficient, or insufficient scale. Consequently, Question 5 and Question 6 results were excluded from the Weighted Average calculation because the scoring scales are incompatible.

TI Subprogram Projects

For the TI subprogram session, reviewers were asked to provide numeric scores (on a scale of 1.0-4.0 in one-half point increments, as indicated above) for Question 1 through Question 5 of each formally reviewed activity. For each reviewed project, the individual reviewer scores for Question 1 through Question 5 were averaged to provide information on the project's question-by-question scoring. Scores for each of these five criteria were weighted using the formula below to create a Weighted Average for each project. This allows a project's question-by-question and final overall scores to be meaningfully compared against another project:

Weighted Average = [Question 1 Score x 0.20] + [Question 2 Score x 0.20] +

[Question 3 Score x 0.40] + [Question 4 Score x 0.10] + [Question 5 Score x 0.10]

Each reviewed TI activity has a corresponding bar chart representing that project's average scores for each of the five designated criteria. As demonstrated in Figure 2, a bullet and error line are included within the green bars representing the corresponding average and standard deviation of criteria scores for all of the reviewed projects in the same subprogram.

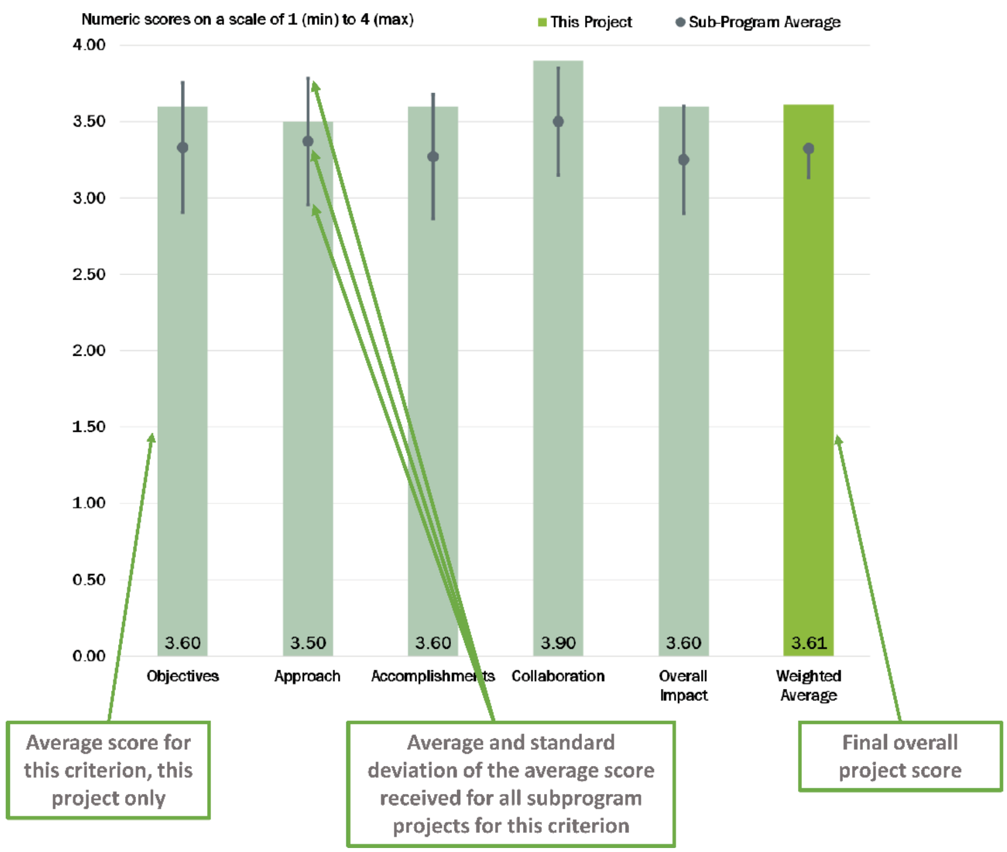

Figure 2. Sample Question 1 through Question 5 score averages, standard deviations, and overall Weighted Average for a TI subprogram project.

For TI projects, Question 1 through Question 5 were rated on a 1.0 to 4.0 scale in one-half point increments, whereas Question 6 was rated on a yes, maybe, or no scale. Consequently, Question 6 results were excluded from the Weighted Average calculation because the scoring scales are incompatible.

Reviewer Responses

Text responses and numeric scores to the questions were submitted electronically through a web-based software application, PeerNet, operated by Oak Ridge Associated Universities (ORAU). Database outputs from this software application were analyzed and summarized to collate the multiple-choice, text comments, and numeric scoring responses and produce the summary report.

Responses to the questions are summarized in this report, with summaries of numeric scores for each technical session, as well as text and graphical summaries of the responses for each individual technical activity. For each project, the reviewer sample size is identified.

Each reviewed activity is identified by Presentation Number, followed by the Presentation Title, the Principal Investigator (PI), and the PI's organization. For each subprogram area, reviewed activities are ordered numerically by project number. Figure 3, below, provides an example project title.

Presentation Number: van016
Presentation Title: Transportation Data Program
Principal Investigator: Stacy Davis (Oak Ridge National Laboratory)

Figure 3. Sample project title with presentation ID, presentation title, PI, and PI organization.

For each project, in addition to the PI, the presenter at the AMR is identified, along with the reviewer sample size. For some projects, the presenter at the AMR was a project team member rather than the PI.

Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that for each question the order of reviewer comments may be different; for example, for each specific project the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc. Not all reviewers provided a response to each question for a given project.

The report is organized by technical subprogram area. Each technical area section includes a summary of that subprogram, reviewer feedback received specific to the subprogram overview presentation(s) given by DOE, a subprogram activities score summary table (and page numbers), and project-specific reviewer evaluation comments with corresponding bar graphs.

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1. Advanced Combustion Engines

The Vehicle Technologies Office (VTO) has a comprehensive portfolio of early-stage research to enable industry to accelerate the development and widespread use of a variety of promising sustainable transportation technologies. The research pathways focus on fuel diversification, vehicle efficiency, energy storage, and mobility energy productivity that can improve the overall energy efficiency and efficacy of the transportation or mobility system. VTO leverages the unique capabilities and world-class expertise of the National Laboratory system to develop innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures; and energy efficient mobility systems. VTO is uniquely positioned to address early-stage challenges due to strategic public-private research partnerships with industry (e.g., U.S. DRIVE, 21st Century Truck Partnership) that leverage relevant expertise. These partnerships prevent duplication of effort, focus DOE research on critical R&D barriers, and accelerate progress. VTO focuses on research that industry does not have the technical capability to undertake on its own, usually due to a high degree of scientific or technical uncertainty, or that is too far from market realization to merit industry resources.

The Advanced Combustion Engines (ACE) subprogram supports early-stage R&D to improve our understanding and ability to manipulate combustion processes, fuel properties, and catalyst formulations, generating the knowledge and insight necessary for industry to develop the next generation of engines and fuels for light- and heavy-duty vehicles. As a result, co-optimization of higher-efficiency engines and high-performance fuels has the potential to improve light-duty fuel economy by 35% (25% from advanced engine research and 10% from co-optimization with fuels) by 2030 compared to 2015 gasoline vehicles. The subprogram supports cutting-edge research at the National Laboratories, in close collaboration with academia and industry, to strengthen the knowledge base of high-efficiency, advanced combustion engines, fuels, and emission control catalysts. The ACE subprogram will apply the unique facilities and capabilities at the National Laboratories to create knowledge, new concepts, and research tools that industry can use to develop advanced combustion engines and co-optimize with fuels that will provide further efficiency improvements and emission reductions. These unique facilities and capabilities include the Combustion Research Facility at Sandia National Laboratories (SNL), Advanced Photon Source at Argonne National Laboratory (ANL), Institute for Integrated Catalysis at Pacific Northwest National Laboratory (PNNL), detailed fuel chemistry expertise at the National Renewable Energy Laboratory (NREL), chemical kinetic modeling and mechanism development at Lawrence Livermore National Laboratory (LLNL), and the Spallation Neutron Source at Oak Ridge National Laboratory (ORNL), along with their high performance computing resources and initial work to utilize future exascale computing resources.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0)*. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 1-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ace001	Heavy-Duty Diesel Combustion	Mark Musculus (SNL)	1-7	3.50	3.50	3.50	3.00	**3.44**
ace022	Joint Development and Coordination of Emissions Control Data and Models (Cross-cut Lean Exhaust Emissions Reduction Simulations (CLEERS) Analysis and Coordination)	Josh Pihl (ORNL)	1-11	3.67	3.67	4.00	3.50	**3.69**
ace023	CLEERS: Fundamentals in Selective Catalytic Reduction (SCR), Filter, and Protocol	Yong Wang (PNNL)	1-15	3.17	2.83	3.33	3.00	**3.00**
ace027	Next-Generation Selective Catalytic Reduction (SCR)-Dosing System Investigation	Abhijeet Karkamkar (PNNL)	1-18	2.80	2.70	2.80	2.70	**2.74**
ace032	Cummins-ORNL Emissions Cooperative Research and Development Agreement (CRADA): NOx Control and Measurement Technology for Heavy-Duty Diesel Engines, Self-Diagnosing SmartCatalyst Systems	Bill Partridge (ORNL)	1-22	3.33	3.17	3.25	3.17	**3.22**
ace033	Emission Control for Lean Gasoline Engines	Vitaly Prikhodko (ORNL)	1-27	3.33	3.50	3.33	3.00	**3.38**
ace056	Low-Temperature Oxidation	Yong Wang (PNNL)	1-31	3.42	3.50	3.42	3.25	**3.44**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ace085	Low-Temperature Emission Control to Enable Fuel-Efficient Engine Commercialization	Todd Toops (ORNL)	1-37	3.17	3.17	3.50	3.33	**3.23**
ace100	Improving Transportation Efficiency through Integrated Vehicle, Engine, and Powertrain Research - SuperTruck 2	Darek Villeneuve (Daimler Trucks North America)	1-40	3.36	3.29	3.21	3.07	**3.27**
ace101	Volvo SuperTruck 2: Pathway to Cost-Effective Commercialized Freight Efficiency	Pascal Amar (Volvo Trucks North America)	1-46	3.14	3.43	3.29	3.14	**3.30**
ace102	Cummins-Peterbilt SuperTruck 2	John Dickson (Cummins-Peterbilt)	1-52	3.29	3.14	3.21	3.14	**3.19**
ace103	Development and Demonstration of a Fuel-Efficient Class 8 Tractor and Trailer SuperTruck	Russell Zukouski (Navistar)	1-58	2.50	2.67	2.92	2.58	**2.65**
ace118	CLEERS Passive NOx Adsorber (PNA)	Janos Szanyi (PNNL)	1-63	3.25	3.13	3.13	3.00	**3.14**
ace119	Development and Optimization of a Multi-Functional SCR-DPF (Diesel Particulate Filter) Aftertreatment System for Heavy-Duty NOx and Soot Emission Reduction	Ken Rappe (PNNL)	1-66	3.00	3.17	3.33	3.00	**3.13**
ace123	Temperature-Following Thermal Barrier Coatings for High-Efficiency Engines	Tobias Schaedler (HRL Laboratories)	1-69	3.25	3.13	3.00	2.88	**3.11**
ace124	SuperTruck 2 - PACCAR	Maarten Meijer (PACCAR)	1-72	3.17	3.17	3.33	3.08	**3.18**
ace128	Reduced Precious Metal Catalysts for Methane and NOx Emission Control of Natural Gas Vehicles	Michael Harold (University of Houston)	1-77	3.50	3.42	3.25	3.42	**3.42**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ace129	Design and Optimization of Structured Multi-Functional Trapping Catalysts for Conversion of Hydrocarbons and NOx from Diesel and Advanced Combustion Engines	Michael Harold (University of Houston)	1-82	3.38	3.25	3.63	3.25	**3.33**
ace130	Development of Passive Hydrocarbon/NOx Trap Catalysts for Low-Temperature Gasoline Applications	Mark Crocker (University of Kentucky)	1-86	3.25	3.13	3.38	3.13	**3.19**
ace135	Towards Predictive Nozzle Flow and Combustion Simulations for Compression Ignition Engines	Gina Magnotti (ANL)	1-90	3.25	2.75	3.25	3.00	**2.97**
ace136	Medium-Duty Diesel Combustion	Stephen Busch (SNL)	1-93	3.17	3.00	2.83	3.00	**3.02**
ace138	Partnership for Advanced Combustion Engines (PACE) - A Light-Duty National Laboratory Combustion Consortium	Paul Miles (SNL)	1-96	3.60	3.20	3.60	3.20	**3.35**
ace139	Development of an Optimized Gasoline Surrogate Formulation for PACE Experiments and Simulations	Scott Wagnon (LLNL)	1-101	3.70	3.60	3.80	3.30	**3.61**
ace140	Improved Chemical Kinetics and Algorithms for More Accurate, Faster Simulations	Russell Whitesides (LLNL)	1-106	3.50	3.50	3.50	3.20	**3.46**
ace141	Advanced Ignition System Fundamentals	Isaac Ekoto (SNL)	1-110	3.40	3.40	3.60	3.30	**3.41**
ace142	Development and Validation of Simulation Tools for Advanced Ignition Systems	Riccardo Scarcelli (ANL)	1-114	3.63	2.88	3.63	3.25	**3.20**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ace143	Fuel Injection and Spray Research	Chris Powell (ANL)	1-118	3.50	3.38	3.50	3.00	**3.38**
ace144	Spray Wall Interactions and Soot Formation	Lyle Pickett (SNL)	1-122	3.80	3.70	3.80	3.50	**3.71**
ace145	More Accurate Modeling of Heat Transfer in Internal Combustion Engines	K. Dean Edwards (ORNL)	1-127	3.20	3.10	3.50	3.10	**3.18**
ace146	Direct Numerical Simulation (DNS) and High-Fidelity Large-Eddy Simulation (LES) for Improved Prediction of In-Cylinder Flow and Combustion Processes	Muhsin Ameen (ANL)	1-131	3.10	3.10	2.70	3.00	**3.04**
ace147	Mitigation of Knock and Low-Speed Pre-Ignition (LSPI) for High-Power Density Engines	Jim Szybist (ORNL)	1-135	3.50	3.50	3.00	3.63	**3.45**
ace148	Overcoming Barriers for Dilute Combustion	Brian Kaul (ORNL)	1-138	3.30	3.40	3.30	3.40	**3.36**
ace149	Cold-Start Physics and Chemistry in Combustion Systems for Emissions Reduction	Scott Curran (ORNL)	1-142	3.20	3.20	3.20	3.30	**3.21**
ace150	Enabling Low-Temperature Plasma (LTP) Ignition Technologies for Multi-Mode Engines through the Development of a Validated High-Fidelity LTP Model for Predictive Simulation Tools	Nick Tsolas (Auburn University)	1-147	3.00	3.08	3.00	3.00	**3.04**
ace151	Hierarchically Informed Engineering Models for Predictive Modeling of Turbulent Premixed Flame Propagation in Pre-Chamber Turbulent Jet Ignition	Haifeng Wang (Purdue University)	1-152	3.20	2.80	3.00	2.80	**2.93**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ace152	Development of High-Fidelity and Efficient Modeling Capabilities for Enabling Co-Optimization of Fuels and Multi-Mode Engines	Matthias Ihme (Stanford University)	1-156	3.10	3.20	3.20	3.20	**3.18**
ace153	Chemistry of Cold-Start Emissions and Impact of Emissions Control	Melanie Moses-DeBusk (ORNL)	1-160	3.50	3.38	3.50	3.25	**3.41**
ace154	Heavy-Duty Hybrid Diesel Engine with Front-End Accessory Drive-Integrated Energy Storage	Chad Koci (Caterpillar)	1-163	3.20	3.20	2.70	3.00	**3.11**
ace155	Low-Mass and High-Efficiency Engine for Medium-Duty Truck Applications	Qigui Wang (GM)	1-167	3.17	3.08	3.25	3.25	**3.15**
ace156	Next-Generation, High-Efficiency Boosted Engine Development	Michael Shelby (Ford)	1-171	3.50	3.50	3.10	3.40	**3.44**
ace157	Low-Temperature Gasoline Combustion for High-Efficiency Medium- and Heavy-Duty Engines	John Dec (SNL)	1-175	3.13	3.38	3.63	2.88	**3.28**
Overall Average				**3.29**	**3.23**	**3.29**	**3.14**	**3.24**

Presentation Number: ace001
Presentation Title: Heavy-Duty Diesel Combustion
Principal Investigator: Mark Musculus (Sandia National Laboratories)

Presenter

Mark Musculus, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 60% of reviewers indicated that the resources were sufficient, 40% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

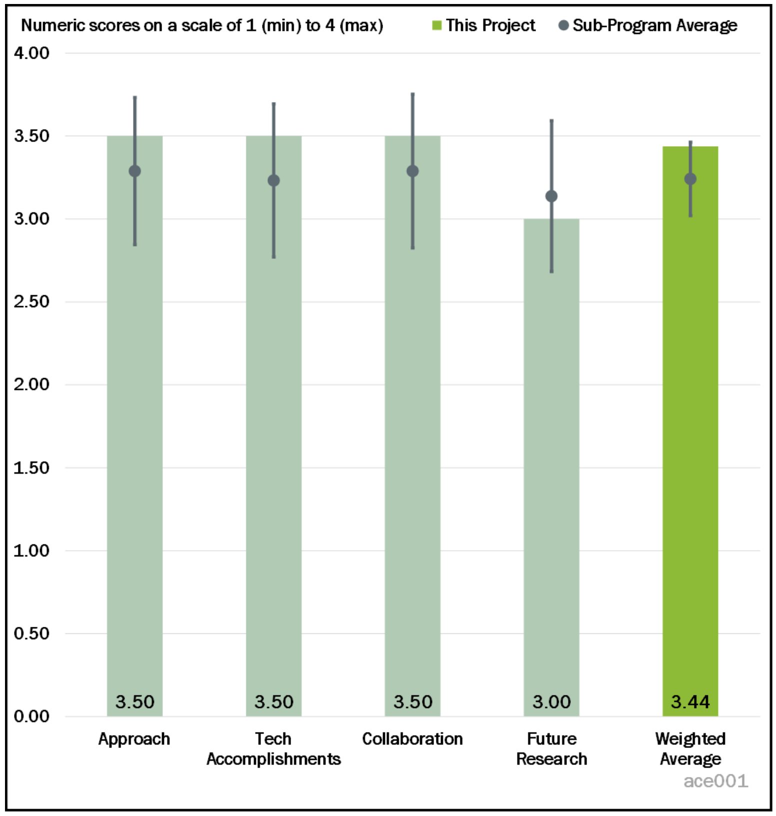

Figure 1-1 - Presentation Number: ace001 Presentation Title: Heavy-Duty Diesel Combustion Principal Investigator: Mark Musculus (Sandia National Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This is an outstanding approach from all aspects—fundamentals, experimental, and computational fluid dynamics (CFD). This is what is always expected from Sandia and people tend to forget how difficult it is to do it consistently. Bravo.

Reviewer 2:

The project is well aligned with the objective of overcoming the barriers to further understanding of combustion and simulation from conventional diesel to low-temperature combustion (LTC), to improve integration of the aftertreatment system for LTC, and to better understand the impact of future fuels on LTC. The team is comprised of great expertise in spray laser diagnostics and simulations (direct numerical simulation [DNS] and Reynolds-averaged Navier-Stokes [RANS]. Each element in the project is complementing each other well. It is not clear, however, if the work will help the LTC aftertreatment system integration directly. Also, while the barrier includes understanding the impact of future fuels on LTC, the plan does not include any alternative fuels. Perhaps it makes sense to plan at least for simulating some alternative fuels.

Reviewer 3:

The team incorporates state-of-the-art experimental and numerical tools. The project focuses a lot of attention on two-injection process. Data are presented giving the motivation, such as enabling the reduction of soot within a range of load. The study provides physical insights to the mechanism associated with the two-injection events, which come from varying approaches, experimental and numerical.

Reviewer 4:
The reviewer was initially concerned whether optical engine results were representative of production engine performance but was encouraged to see that there are plans for future partnerships with parallel metal engine experiments. That being said, the project is making progress in addressing technical barriers in our understanding of combustion and simulation from conventional diesel to LTC. However, there seems to be no plans in addressing the impact of multi-component fuels on LTC.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Results are very descriptive, and the progress made since the project started is very good.

Reviewer 2:
It looks like the team has made a good progress. Leveraging the cutting-edge laser diagnosis technology is a great element in the project. Also, it is great to see the world-class DNS being used to understand the ignition characteristics and flame development. One request for the team is to prepare a slide clearly indicating the current progress relative to the goals and milestones.

Reviewer 3:
According to the reviewer, experiments and simulations have been effectively leveraged to demonstrate valuable insights in the interaction between first and second injection pulses. The establishment of the fact that ignition of the second injection is dominated by auto-ignition, not flame propagation, is very much appreciated. However, could we also extend our understanding of the impact of a third injection pulse and even more?

Reviewer 4:
The study aims at uncovering the fundamental physics of combustion and emission formation. To this end, the team's work is of high quality. It may be helpful for the PIs to make an assessment on the overall progress of this study over the course of the last 10 years. To what extent have these studies improved the capability of engines to attain a higher efficiency - low emissions target? How much wider of an operation range has been enabled by the improved understanding of the physical process?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There is solid collaboration between academia and industry partners.

Reviewer 2:
The reviewer was impressed by the amount of collaboration between the various parties involved in the project and how fast results can come when people are really working together toward a common goal.

Reviewer 3:
As mentioned before, the team is well organized and complementary teams are supporting each other very well.

Reviewer 4:
There are excellent members in the team. Members range from industry partners to universities. There is a concentrated effort to make the findings known. The presentation did not appear to give information regarding how the work undertaken is being assimilated by industry. One of the many engine original equipment manufacturers (OEMs) could be tasked to bridge this gap.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Future work is very clear, and milestones were clearly identified.

Reviewer 2:
Research includes the overarching goal to develop conceptual models, and tools are well covered. The team could have been more specific as to test conditions, especially seeking conditions that are tied to yielding notable improvements to the engine efficiency and emissions state of the art. Barriers 2-3 from Slide 2 (after treatment integration and future fuels) received no notice in the materials presented.

Reviewer 3:
The proposed future research looks good. It is not clear if any emission or temperature tracking is planned for helping the aftertreatment system integration/application.

Reviewer 4:
The reviewer commented that extensive materials were provided for the technical accomplishments, but the proposed future work seems sketchy and was not clearly elaborated.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer affirmed that, yes, this project supports the overall United States (U.S.) Department of Energy (DOE) objectives because it focuses on the development of the science base of in-cylinder spray, combustion, and pollutant-formation processes for both conventional and low-temperature combustion that is needed by the industry to design and build cleaner, more efficient engines.

Reviewer 2:
The project is well aligned with the DOE objectives to come up with a way for more fuel efficiency and cleaner energy utilization.

Reviewer 3:
There is no improvement in efficiency or emissions without understanding the fundamentals of combustion. This project is doing just that.

Reviewer 4:
The project work is relevant and, as suggested previously, could gain from a closer collaboration with industry, specifically attempting to correlate the work with conditions seen in real life applications. For example, how do the models help extend the use of dual injections to further mitigate soot and improve the engine efficiency?

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project is being reported as 50% complete at the mid-way point of a 3-year program.

Reviewer 2:
The reviewer commented that resources are adequate.

Reviewer 3:
It looks like the team has sufficient resources.

Reviewer 4:

The reviewer remarked that it is ridiculous how little money goes to National Laboratories and academia that do so much innovative work.

Presentation Number: ace022
Presentation Title: Joint Development and Coordination of Emissions Control Data and Models (Cross-cut Lean Exhaust Emissions Reduction Simulations (CLEERS) Analysis and Coordination)
Principal Investigator: Josh Pihl (Oak Ridge National Laboratory)

Presenter

Josh Pihl, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

All reviewers indicated that the project was relevant to current DOE objectives. 33% of reviewers indicated that the resources were sufficient, 33% of reviewers indicated that the resources were insufficient, while the remaining reviewers indicated that the resources were excessive.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

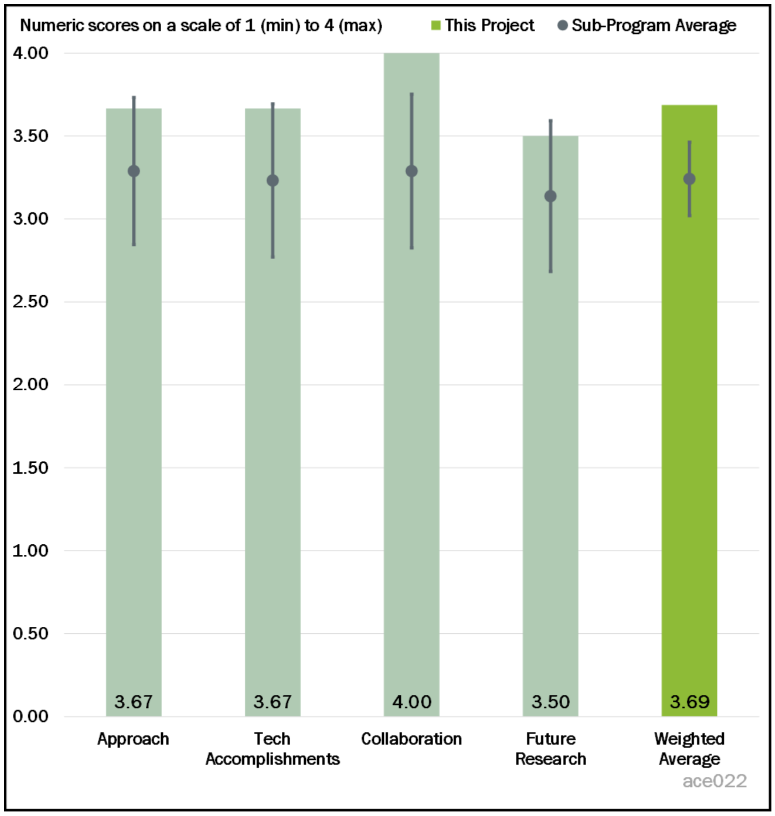

Figure 1-2 - Presentation Number: ace022 Presentation Title: Joint Development and Coordination of Emissions Control Data and Models (Cross-cut Lean Exhaust Emissions Reduction Simulations (CLEERS) Analysis and Coordination) Principal Investigator: Josh Pihl (Oak Ridge National Laboratory)

Reviewer 1:

The reviewer affirmed a great job in coordinating the collaboration activities including the Crosscut Lean Exhaust Emissions Reduction Simulations CLEERS conference and the teleconferences. The team should be commended for responding quickly to the Industry Priorities Survey in ramping down the passive oxides of nitrogen (NO_x) adsorber (PNA) work and ramping up the hydrocarbon trap (HCT) work and selective catalytic reduction (SCR) aging work. CLEERS is a good blend of coordination activities and technical work.

Reviewer 2:

The approach is well focused and spot on. The questions address the needs of the industry. The team has been creative in its approach, resorting to surveys, modeling, and testing. The industry dialogue that the team has created allows pre-competitive exchange of ideas and findings. Years after the DOE's Directions in Engine-Efficiency and Emissions Research (DEER) conference discontinued, CLEERS has done a nice job filling its vacuum and the gap created due to the absence of DEER. If CLEERS will not do it, who will?

Reviewer 3:

CLEERS activities and research and development (R&D) involve a coordinated effort between National Laboratories, industry, and academia. This coordination provides an abundance of expertise and resources to address the critical barriers in emissions reduction technology. Development of catalysts, discerning the operational boundaries, and studying the effects of aging of low-temperature exhaust conditions is vital for realizing low emissions profile from both clean diesel and lean spark ignition (SI) platforms. The project partners are well equipped with resources to develop the models and validate with experimental results.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer has been involved with and watching CLEERS since its inception. It is rare that the reviewer rates “Outstanding,” but in all fairness CLEERS checks all the boxes and has exceeded its initial charter and expectations. Not only has it shown due progress and adapting to and meeting both the DOE and the industry’s needs, it is also led by an intelligent, pro-active, and dynamic team continually monitoring the latest changes in the emission control field.

Reviewer 2:
The reviewer affirmed a nice study on the adsorption of different hydrocarbons on the uncatalyzed zeolite beta (BEA) formulation. Also, there is a very nice fit of the ammonia (NH_3) storage and release data with the copper (Cu)/aluminosilicate zeolite (SSZ-13) sample as a function of the storage temperature, aging temperature, water (H_2O) concentration, and NH_3 concentration.

Reviewer 3:
The CLEERS workshops for 2019 and 2020 have been successfully organized and results related to nitric oxide (NO) adsorption model and palladium (Pd)-zeolite PNA has been disseminated. In addition, measurements for HC adsorption on a zeolite-based HC trap has been completed. The 2019 CLEERS Industry Priorities Survey is an excellent way to communicate with industry stakeholders to assess the imminent topics that need to be addressed as part of government-funded research. As expected, SCR-related topics for heavy duty (HD), medium duty (MD), and light duty (LD) vehicles ranked the highest in importance. This is in line with the industry challenges with respect to upcoming California Air Resources Board (CARB) regulations and the need for the diesel industry to further reduce NO_x emissions. Complex aftertreatment packages may not be preferred by engine manufacturers; rather, the focus should be aimed at understanding inefficiencies in current SCR and also developing close-couple catalyst technologies for these platforms. Using SCR on the filter is another upcoming technology that needs better understanding. Overall, the technical accomplishment of this project is excellent.

An additional question related to the accomplishment is—for the tasks involving the study of SCR aging and its impact on ammonia inventory—whether the project will focus on unwanted species that are formed during urea decomposition that could potentially be occupying ammonia adsorption sites on the SCR catalyst. The reviewer believed that such a mechanism was proving to be a critical barrier to realizing high NO_x conversion efficiency in real-world operation.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration appears strong. Coordination seems streamlined with good feedback channels and communication with the industry.

Reviewer 2:
CLEERS does a tremendous job in promoting collaboration among industry researchers on vehicle emission controls. The CLEERS conference and monthly teleconferences provide very effective forums for sharing pre-competitive emissions data with peers from other companies and institutions. The Priorities survey also highlights the emission control topics that currently need to be prioritized. CLEERS also has good collaboration with Professor Bill Epling of the University of Virginia (UVA), Johnson Matthey (JM), Pacific Northwest National Laboratory (PNNL), the Advanced Combustion and Emission Control (ACEC) tech team, and the Advanced Engine Crosscut team.

Reviewer 3:
Many of the accomplishments shown in this project were not possible without outstanding coordination between the teams. Collaboration with UVA has generated interesting results for PNA NO storage. The involvement of JM for catalyst material and PNNL for modeling is also vital.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The team has done an outstanding job listening to the industry needs, summarizing them in a concise fashion, and communicating them across the greater emission control community. Some of the gathered information has been used creatively to also address some of the needs, e.g., via modeling or testing. What appears to be missing is expanding into cross-functional industry collaborations to fill some of the gaps of immense industry needs. This is indeed the vision that late Dr. Stuart Daw, one of the main CLEERS architects, had in mind.

It appeared to the reviewer that one of the clear needs at this juncture in industry is a strong, low-temperature SCR catalyst yielding 90% or higher activity at about 150°Celsius (C). This fits well with DOE’s goal of advancing fuel economy, since low-temperature SCR of NO_x is a strong, fuel economy strategy. Some of the estimates, which have been seen, indicate up to 7% fuel economy, should such SCR technology become available. Despite years of industry discussions, no one seems to want to take the lead for a collaboration, perhaps due to its competitive nature. With all the activities going on in low-temperature NO_x reduction, CLEERS—and perhaps CLEERS only—is in a unique position to fill such a gap, making a long-term impact on this industry as well as enabling a novel route to fuel economy, itself significant for the DOE’s charter.

Reviewer 2:
The collaboration and coordination work definitely need to continue with the CLEERS conference and teleconferences. The HCT work needs to be expanded to include catalyzed HCTs so the oxidation of the stored HC species can be studied. This will be challenging for stoichiometric applications since there is no excess oxygen with which to oxidize the hydrocarbons (HCs), so methods to introduce oxygen (e.g., oxygen storage component [OSC], air injection) will need to be studied. The effects of different aging conditions (rich, stoichiometric, lean) on the HCT would also be useful. The SCR work on NH_3 storage also needs to be expanded to include NO_x conversion.

Reviewer 3:
Future research focuses on PNA, HC traps, and urea SCR catalyst. The SCR-catalyst-related work is highly important; however, the reviewer indicated a couple of questions remain related to future research work. Is PNA still a viable solution for low-NO_x, low-fuel consumption targets? For which type of application is the work related to PNA targeting? Because PNA is less favored for future emissions standards, targeting a certain application where PNA would be favored will add value to the model outcomes.

The industry is finding it hard to understand the underperformance of SCR under real-world conditions. Many factors may contribute to this underperformance—aging, deposit formation, uncharacteristic deterioration based on duty cycle, fuel impurities, etc. In order to be responsive to industry challenges, work in this direction can be addressed along with aging-related work.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer remarked that CLEERS supports the DOE charter of fuel saving strategies and close interactions with the industry, above and beyond its initial charter. It is hard to think of pre-competitive discussions in this industry without CLEERS’s contributions. The reviewer encourages DOE to provide more resources and

funding for CLEERS so it can expand on the outstanding value it brings to the government, industry, society, and environment. It is a win-win across all the stakeholders.

Reviewer 2:
The CLEERS conferences and telecoms provide a great forum for sharing technical data with peers from other companies and thereby promoting pre-competitive collaboration. The study of emission control technologies that allow fuel-efficient engines to go to market while meeting the appropriate emission standards is paramount for supporting the DOE objective of reducing our dependence on foreign oil.

Reviewer 3:
The project addresses important issues related to catalyst development for future emissions standards. The project was also instrumental in receiving feedback from industry to develop current and future direction of research.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer indicated that a group of 33 industry entities, 23 academic institutions, and 12 National Laboratories together had all the resources to address all the milestone set forth in this study.

Reviewer 2:
The resources appear to be adequate for now, although there might be a need for more experimental and modeling resources in order to expand the HCT work to include HC oxidation as well as the effects of aging. The expansion of the SCR work to include NO_x conversion could also require additional resources.

Reviewer 3:
The reviewer has marked the project as "Insufficient." Although CLEERS does meet its goals, it also appears to have become resource-strapped given the recent (last 2-4 years) expansions in its activities and goals. In the opinion of this reviewer, given its broad-reaching impacts, providing it with more resources is warranted and will certainly create even a far stronger "value to cost" ratio.

Presentation Number: ace023
Presentation Title: CLEERS: Fundamentals in Selective Catalytic Reduction (SCR), Filter, and Protocol
Principal Investigator: Yong Wang (Pacific Northwest National Laboratory)

Presenter

Yong Wang, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

All of reviewers indicated that the project was relevant to current DOE objectives and the resources were sufficient.

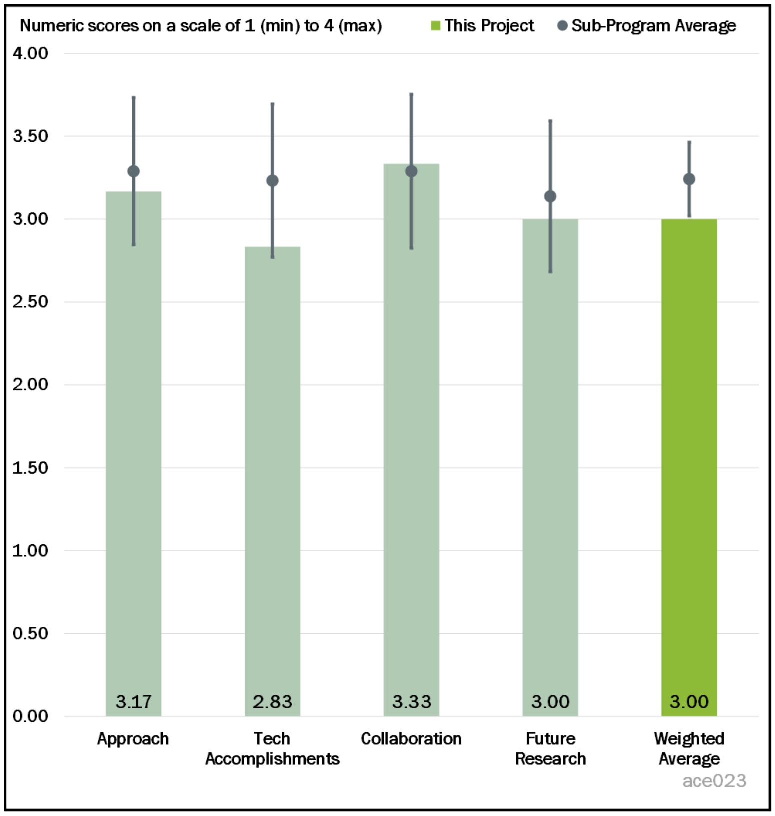

Figure 1-3 - Presentation Number: ace023 Presentation Title: CLEERS: Fundamentals in Selective Catalytic Reduction (SCR), Filter, and Protocol Principal Investigator: Yong Wang (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach to this work is sound. PNNL is utilizing its high-performance computing resources and bench-scale experimentation to answer key questions in three-way catalyst (TWC) and SCR catalyst development.

Reviewer 2:

The reviewer stated that this is good work, targeting reduced platinum group metal (PGM) loading and low-temperature catalyst performance. There are good observations reported here, such as the impact of sulfur (S). The overall findings, however, appear minimal, given that they reflect a full year of activity blessed with sufficient funding, testing means, advanced characterization tools, and modeling resources across two National Laboratories, several OEMs, one Tier 1 supplier, and three universities (some had indirect roles). It is likely more could have been achieved.

Reviewer 3:

(PNNL makes good use of its vast capabilities in fundamental science to advance the development of emission control catalysts. Instead of focusing on one topic like other PNNL projects, this particular project is a hodgepodge of different catalyst technologies including SCR catalysts, rhodium (Rh) and Cu catalysts, particulate filter development, and catalyst testing protocol development. It might be good to break up this project into several smaller projects where each is focused on one catalyst technology.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer called this a nice study on the effects of sulfur poisoning and desulfation on the single-atom Cu/cerium (Ce) catalyst. It is also very nice work on investigating the NO_x conversion of the single-atom Rh/Ce catalyst; the results highlight the importance of including H_2O on all the tests, since H_2O is always present in automotive exhaust. The Rh/Ce catalyst should be tested at stoichiometry and not the very rich conditions that were used (1,750 parts per million [ppm] CO, 460 ppm NO); this would probably reduce the NH_3 formation on the test with H_2O. Also, it is a nice job on the addition of manganese (Mn)/Ce to the SCR catalyst to increase the NO_2 formation for the SCR catalyst and thereby allow the feed gas nitrogen dioxide (NO_2) to be used for soot oxidation. The effects of sulfur poisoning on this catalyst definitely need to be investigated because Mn forms stable sulfates. The reviewer noted the outstanding job of taking the lead on developing the catalyst testing protocol.

Reviewer 2:

The SCR low-temperature activity appears to be still around 80% even in the presence of Mn-Ce oxides. Are there other approaches to push this conversion higher, or are we reaching the limits of catalyst conversion efficiencies?

Activities related to TWCs show interesting results of almost over 90% NO reduction for temperatures as low as 100°C. One question related to TWC research is how representative are these results for TWC used in natural gas vehicles? The TWCs in natural gas (NG) vehicles seem to undergo significant degradation faster than that in gasoline applications. Is there work being done to understand this aspect or translate these findings to natural gas vehicle (NGV) exhaust?

Reviewer 3:

The work quality is good; however, it is the understanding of this reviewer that the accomplishments are modest relative to the capability and resources of both the core and the broader team.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that there is good collaboration with General Motors (GM), the University of New Mexico, and Washington State University on the single-atom catalysts.

Reviewer 2:

It appeared to the reviewer that the coordination looks good. The principal investigator (PI) has done a good job cross-functionally synergizing the characterization capabilities, modeling, and testing resources across the core team, and reasonably across the broader team.

Reviewer 3:

The collaboration with Cummins, Fiat Chrysler Automotive (FCA), and Kymanetics lends value and direction to this study. It would be interesting to involve Cummins for TWC related work since Cummins is a leading NGV engine manufacturer, input on issues related to TWC for NG applications is important as well.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The SCR-related future work listed in the presentation is valuable and highly important with regard to specific topics related to examining aged, on-road catalysts. The reviewer believed this will lend the most value to this study. Aging of closed couple SCRs in heavy-duty applications also needs to be considered. The reviewer commented that there is no mention of natural gas related TWC work and a decrease in NO_x reduction with age. Additionally, the opined that work related to selective catalytic reduction filter (SCRF) is also valuable.

Reviewer 2:
The reviewer remarked that the plan for “Future Work” could possibly benefit from some modifications. Though a key focus on this project is “low temperature” performance, only one out of seven tasks appears to have a low-temperature focus. The task “Conduct fundamental filtration experiments to understand effects of porosity variation across the thickness of ceramic exhaust filter walls” has been extensively studied by honeycomb suppliers and coaters. There are also several publications on flow patterns in pores of a wall-flow device. Studying such literature would propel this work forward more speedily.

Reviewer 3:
The reviewer stated that the project team needs to look at the effects of sulfur poisoning and thermal aging on the single atom Rh/Ce catalyst. Since this is being developed as a TWC, aging temperatures of 900° to 950°C need to be assessed while using the ACEC aging protocol (neutral/rich/lean aging). The OSC of the Rh/Ce catalyst needs to be assessed, because OSC is so important for TWCs. The light off tests need to be assessed with air to fuel ratio (A/F) dithering to simulate actual vehicle operation. Also, the team needs to investigate sulfur poisoning and desulfations on the Mn-Ce-modified SCR catalyst, since sulfur inhibits the low-temperature activity of SCR catalysts.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project supports overall DOE goals by addressing critical barriers and issues related to advanced NO_x reduction catalysts. Improvements in catalyst efficiency are vital to improving engine efficiency.

Reviewer 2:
The reviewer commented that low-temperature performance is synonymous with fuel savings (either via optimized combustion or cold-flow fuel savings). Thus, the work fundamentally coincides with the DOE objectives.

Reviewer 3:
PNNL is developing catalysts for low-temperature operation, which will be needed to meet the Tier 3 Bin 3 emission standards with future fuel-efficient engines that generate lower exhaust temperatures.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The team has some of the world’s best characterization resources, tools, and brain power. Resources are not a concern in this project.

Reviewer 2:
The PNNL high-performance computing resources are well equipped to perform high fidelity model development. Micro-reactor test benches available with industry partners can also help achieve goals of the study.

Reviewer 3:
The resources appear to be sufficient for the current workload.

Presentation Number: ace027
Presentation Title: Next-Generation Selective Catalytic Reduction (SCR)-Dosing System Investigation
Principal Investigator: Abhijeet Karkamkar (Pacific Northwest National Laboratory)

Presenter

Abhijeet Karkamkar, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

All reviewers indicated that the project was relevant to current DOE objectives. 80% of reviewers indicated that the resources were sufficient while the remaining reviewers indicated that the resources were insufficient.

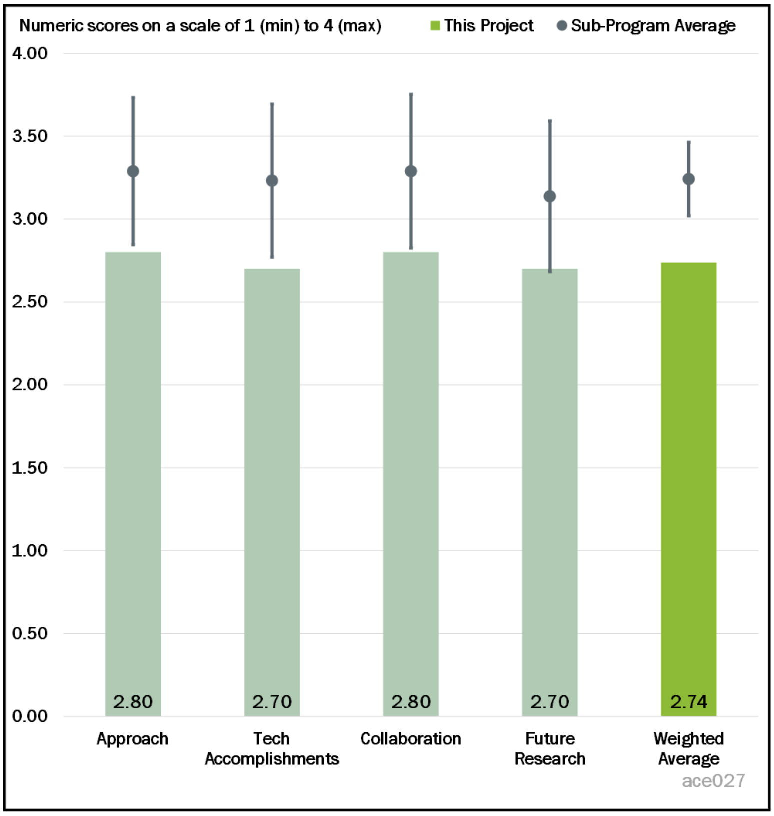

Figure 1-4 - Presentation Number: ace027 Presentation Title: Next-Generation Selective Catalytic Reduction (SCR)-Dosing System Investigation Principal Investigator: Abhijeet Karkamkar (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach to this project has improved in the past year for the reviewer, as it has focused on an important issue in urea hydrolysis and on new storage materials.

Reviewer 2:

The project reports on a solid-material approach of storing and releasing NH_3 to tackle emissions under 180°C, albeit this is a huge distance from real-world application for the foreseeable future.

Reviewer 3:

The approach of looking for new catalysts that can decompose urea at low temperature without forming isocyanic acid (HNCO) and then store NH_3 is good. But, quantification for the effectiveness of these material is not provided. There is no other matrix presented than NH_3 storage capacity. Further, effectiveness of few high-ranking materials from this study could be pursued further for their practical application and challenges (cost, volume needed, chemical hazard analysis, etc.).

Reviewer 4:

This work has generated some interesting and relevant data, and the investigation of NH_3 storage from urea is sensible considering the current state of the art in NO_x abatement, but the project seems to leap around in terms of focus from year to year in response to reviewer comments. The responsiveness is good, but it gives the impression of improvisation as opposed to planning. The technical milestones are also poorly defined, and do not appear to align with the technical accomplishments presented.

Reviewer 5:
Given the growing interest in using close-coupled SCR catalysts on future heavy-duty diesel engines to meet future ultra-low NO_x emission limits (see Southwest Research Institute [SwRI]/ CARB heavy-duty low NO_x test program results), how does this project fit with the use of close-coupled SCR catalyst on a heavy-duty diesel engine? Perhaps the search for a better urea hydrolysis catalyst still has some merits, but the reviewer was not sure an ammonia storage agent is important for achieving future ultra-low NO_x emission targets.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Progress has been made in identifying a urea hydrolysis catalyst that limits production of isocyanic acid. The project has also identified some interesting zeolite-based ammonia storage materials.

Reviewer 2:
The oxide catalysts for largely reducing isocyanate as a product of the urea hydrolysis are very interesting. More data on their actual use are important, because these would be put in existing commercial systems. The work on titania-silica catalysts for ammonia storage is also interesting but should be pursued further.

Reviewer 3:
The NH_3 storage and desorption behaviors have been investigated on multiple materials to enable the down selection process. It is not clear whether the team has the chemistry and materials insight to identify the most promising materials. The choice of materials seems to heavily rely on recommendations instead of theory guided choices.

Reviewer 4:
A key barrier to practical application of these NH_3 storage materials—competition with H_2O—is not addressed. Though it is mentioned as a future goal, the reviewer was not sure how effective it would be in such a short duration as the project is ending in September 2020. Additionally, this whole exercise looks like a screening process without putting more emphasis on the science of urea decomposition and storage of NH_3 so that material having minimum effect of competing species (e.g., water) can be selected.

Reviewer 5:
The reviewer does not doubt the quality of the work being done, but the presentation of the results lacks clarity. Of the barriers presented, only "New materials to address the 150°C" is addressed. The technical milestones and the technical accomplishments do not match. That being said, the reviewer was interested to see the outcome of the hydrolysis catalyst work and its impact on deposit formation.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaborations with groups within United States Council for Automotive Research (USCAR) have been useful. Interaction with more groups outside of USCAR would also be helpful.

Reviewer 2:
The project seems be running with constrained resources despite a good intention. It is understandable, given the funding level.

Reviewer 3:
Collaboration appears to be primarily through scheduled meetings with USCAR. Consultation with industry is also mentioned, but no substantial involvement is indicated.

Reviewer 4:
It is mentioned that the USCAR team is well aware of findings and provides its voice to the project. It would be better if the team is involved in discovering the science and then applying it.

Reviewer 5:
More feedback from industry is needed on whether an improved urea hydrolysis catalyst or another ammonia storage material is needed to meet future heavy-duty, ultra-low NO_x targets.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
According to the reviewer, the proposed future research is well chosen to look at materials issues in this challenging area.

Reviewer 2:
Some of the tasks mentioned in future work should have been done upfront (e.g., mechanistic studies effect of H_2O) so better materials could have been selected. Zeolite modification is a broader topic and more insight has not been provided. Alternative development pathways are also not provided.

Reviewer 3:
The proposed future work is a logical continuation of the work presented here. It is difficult to tell if it aligns with the proposed technical milestones.

Reviewer 4:
The proposed work is a reasonable direction. However, it is overloaded with the limited amount of time and resources.

Reviewer 5:
Given the growing interest in using close-coupled SCR catalysts on future heavy-duty diesel engines to meet future ultra-low NO_x emission limits, is this project still relevant? Perhaps the search for a better urea hydrolysis catalyst still has some merits, but the reviewer was not sure the world needs another ammonia storage agent.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is focused on developing an alternative source of NH_3 for the SCR catalyst on diesel vehicles that will allow NO_x conversion below 180°C, the temperature where the current source of NH_3 (urea) decomposes. Such an NH_3 source would be helpful for providing NO_x conversion at lower temperatures with advanced SCR catalysts and also for reducing the extra fueling currently required to maintain the exhaust temperatures above 180°C during low load operation.

Reviewer 2:
A low-temperature NH_3 supply is necessary for low-temperature NO_x abatement, which allows for fuel efficiency while meeting emission regulations.

Reviewer 3:
If the project is successful in allowing earlier low-temperature (T) light-off of ammonia SCR catalysts, this project is very relevant in meeting low energy efficiency in emissions control.

Reviewer 4:
Future emissions regulations for light-duty and heavy-duty diesel would require efficient NO_x conversion at low temperatures, and providing suitable reductant at these low temperatures is critical for NO_x conversion. There are other alternatives to low temperatures, such as hybridization or operating the engine at high temperatures to avoid these low-temperature regimes, but those come at higher cost of the product or higher greenhouse emissions. Therefore, industry is really looking for the technology of reductant delivery at low temperature without deposit formation.

Reviewer 5:
The reviewer understands the interest in this project to support low-temperature NO_x performance, but given the growing interest in using close-coupled SCR catalysts on future heavy-duty diesel engines to meet future ultra-low NO_x emission limits, is this project still relevant? Perhaps the search for a better urea hydrolysis catalyst still has some merits, but the reviewer was not sure the world needs another ammonia storage agent. The reviewer indicated that this is a repeat of comments on this project’s future work.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project appears to have sufficient resources to complete the remaining milestone by the end of the project schedule later this year.

Reviewer 2:
Resources are very sufficient for this project at PNNL.

Reviewer 3:
The reviewer said that resources are sufficient.

Reviewer 4:
The funding level appears to be sufficient for the work performed.

Reviewer 5:
The project is delivering preliminary material selections under simple and ideal conditions. A significant amount of coordinated engineering effort is required to strengthen the research, and many fundamental aspects of the research remain premature.

Presentation Number: ace032
Presentation Title: Cummins-ORNL Emissions Cooperative Research and Development Agreement (CRADA): NOx Control and Measurement Technology for Heavy-Duty Diesel Engines, Self-Diagnosing SmartCatalyst Systems
Principal Investigator: Bill Partridge (Oak Ridge National Laboratory)

Presenter

Bill Partridge, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

All reviewers indicated that the project was relevant to current DOE objectives and the resources were sufficient.

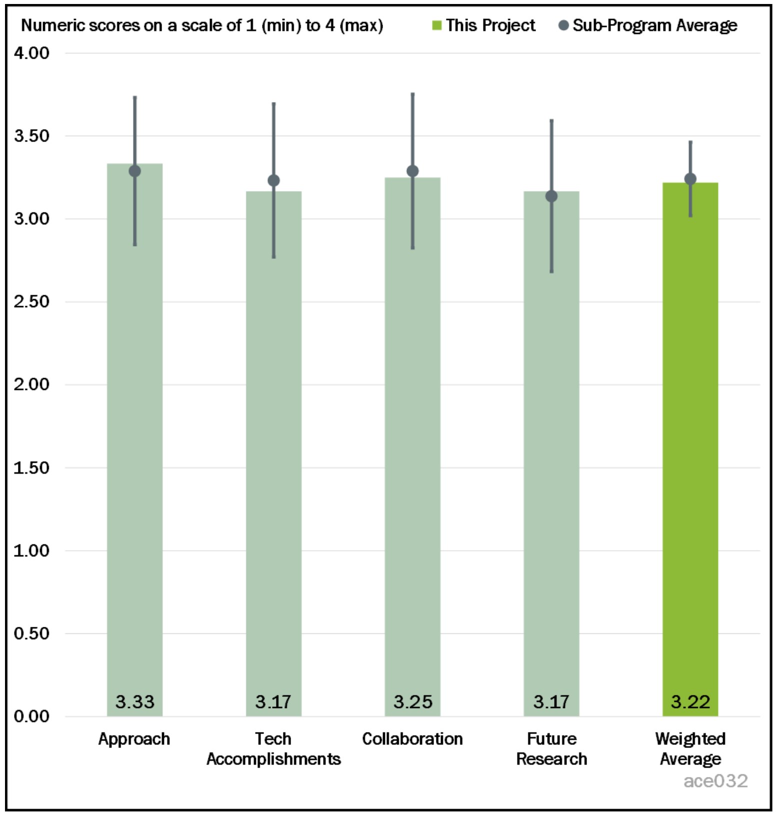

Figure 1-5 - Presentation Number: ace032 Presentation Title: Cummins-ORNL Emissions Cooperative Research and Development Agreement (CRADA): NOx Control and Measurement Technology for Heavy-Duty Diesel Engines, Self-Diagnosing SmartCatalyst Systems Principal Investigator: Bill Partridge (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The group has focused on understanding the aging mechanisms of Cu/SSZ SCR catalysts. The project team found specific features in the activity profiles as a function of temperature that change with aging and describe the kinetic half cycles of the reaction. The project team hopes to use these to determine specifics of the aging and how to incorporate such findings into models and better designed systems. With this unique approach, the project team is addressing the technical barrier–understanding field-aged samples that have yet to be mimicked with lab-aging protocols. The reviewer asserted that the project team has a well-designed plan.

Reviewer 2:

The presentation and project did a nice job of making the case for the context of the work and how field aging is distinct from hydrothermal lab aging and must be studied and modeled. The introductory material also showed well how the current project is distinct and fits into the larger collective of low-T emissions projects.

The approach taken seems very reasonable by building a transient response apparatus, collecting data, and modeling and then moving to systems of commercial relevance. While the combination of the components of this approach do not strike this reviewer as very “outside the box”, nonetheless it seems effective and appropriate for a goal-oriented project.

Reviewer 3:

This project has a goal of determining the kinetics of the entire cycle of the NH_3 SCR reaction with a focus on low-temperature kinetics to improve its use in HD NO_x remediation. This relatively unique approach gains data from a transient response reactor to use in a global-kinetic model. One useful addition to the approach was data taken on a field-aged versus a lab-aged catalyst.

Reviewer 4:
The project thus far has focused on developing a half-cycle-based kinetic model for SCR catalyst performance. In the subsequent work, the team will use field-aged catalysts to look at how the kinetic parameters have changed. The reviewer asserted that this should lead to further understanding the key SCR catalyst deactivation mechanisms found in the field.

Reviewer 5:
The project, which is focused on understanding field-aging of SCR catalyst, is well planned and targets several key aspects of aging. It includes modeling, kinetics considerations, and testing. The team is capable and includes a major engine OEM and catalyst supplier. If integrated in engine operation (to synchronize engine-catalyst operations as a model-based control) and successful, it could result in better SCR operations, system efficiency, and overall fuel economy as well as improved durability and full useful life.

The reason this evaluation is rated “Good” (not higher) is that there was no strong evidence shown that any major attempt has been invested in the project thus far. There is no strong evidence (except lightly pointing to it) seen in the project displaying what that may look like—when, how, plan, timeline, specific objectives, etc.—while the project has progressed more than 50% thus far.

Reviewer 6:
More stringent durability requirements for HD aftertreatment are expected from regulatory agencies in the coming year. Therefore, the development of viable approaches for diagnosing the state of a SCR catalyst for HD diesel applications is highly desirable from an OEM perspective. The method proposed here to monitor the state of the catalyst through a conversion inflection (CI) phenomenon is unique and offers the potential to predict the catalyst performance. However, in order to quantify the state of the catalyst, the method relies heavily on its ability to differentiate the cause of degradation and whether or not the entire SCR is affected. This requires known, in-field aging processes, which have not been demonstrated over the multiple years of this project. Being able to separate and quantify the contributions from each of the aging mechanisms on the CI phenomenon will be very challenging.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Milestones seem to be on track for a project about halfway through its cycle. Overall, the team seems to address the majority of comments from prior reviews sufficiently. No aspect of the project seems to be lagging, the reactor is working, data are being collected, and the fitting seems to be moving to the point of applying the overall methodology to “real” systems. The reviewer noted that, in the slides and presentations, it would be helpful to better delineate data that are experimental versus fitted. The backup slides did this well, but it was not always clear to the reviewer in the presentation itself.

Reviewer 2:
The reviewer commented so far, so good, in developing the half-cycle model. Now comes fitting the model to field-aged hardware and linking those results to real world degradation mechanisms.

Reviewer 3:
The progress is good, noticeable, and tangible compared to its state last year. Kinetics considerations and testing (hydrothermally aged, HTA) and sulfur poisoning) have been accomplished and are further in progress. New Cummins team members, especially for modeling, have been integrated into the project.

Thus far, this project has largely focused on sulfur and temperature impacts, but not that of lube oil. The presentation only lightly mentions lube oil impact. Some studies have shown that some SCR field aging/poisoning impacts could be attributed to lube oil species (iron (Fe), potassium (K), phosphorus (P), etc.), though they have been typically reported not to be as serious as the impact of sulfur and vary depending on the catalyst type. With more than half of the project now completed, it is worthwhile for the project to investigate such impacts as well, especially since kinetics considerations are a major part of this study.

Reviewer 4:
Model development and parameter fittings are key accomplishments. The fitting of the data provides confidence in the model and approach the team is using. The new reactor should accelerate results gathering. The reviewer posed a question about whether the degradation mode will actually correlate to the data as this could be elusive. However, the project team has shown that it can obtain the needed data for the half cycles that describe the SCR reaction, and the upcoming annual cycle will provide the team with the aged catalyst data and allow testing the working hypothesis.

Reviewer 5:
A portion of what was presented in this update has been discussed in prior updates. Although the kinetic development is important, it will be difficult to differentiate the catalyst behavior resulting from different aging mechanisms. While the approach is novel, the level of progress in the past year is less than expected. It appeared to the reviewer that significant effort would be applied to building a reactor system, when one should already be available either within Oak Ridge National Laboratory (ORNL) or at Cummins to perform that work. More effort should be spent evaluating the field-aged sample in terms of correlating the performance of the SCR substrate along its length to the actual state (physical and chemical) of the sample along its length. That will help link the state of each portion of the catalyst to the overall performance and allow better modeling. The effects of oil poisons, PGM poisons, and thermal aging will have to be taken into consideration.

Reviewer 6:
A wide range of kinetic parameters was determined and used in the model. A major and interesting finding is that the field-aged catalyst data do not appear to be reflected well in the data from lab-aged catalysts. Some major efforts remain to reach the project goals.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
According to the reviewer, an excellent set of partners is on the project.

Reviewer 2:
There is obvious collaboration between ORNL and Cummins. The participation of (JM in the project was not made obvious by the presentation, unless it was the catalyst supplier.

Reviewer 3:
Cummins will need to do more in the coming year to help link modeling results with field-aging degradation mechanisms.

Reviewer 4:
Collaboration includes ORNL, Cummins, and JM. This is a strong team, but the reviewer had a feeling that some of the deep, fundamental insight is missing. Integration of a catalyst chemist from academia well versed in catalyst aging is something to think about.

Reviewer 5:
The slides and presentation could have done a better job delineating who did what, i.e., what were the specific contributions spread across the various partners. A separate slide showing a discrete example of how the team

worked together on each component of the work (reactor, data collection, and data modeling) would have been powerful in convincing reviewers the project team provides a sum greater than the parts.

Reviewer 6:
The collaboration on this project appears appropriate but appears to lack timely results. Also, the inclusion of a sensor supplier would help provide greater insight on how to accurately measure the NO_x and NH_3 in a vehicle application.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The upcoming work plan begins the processes of understanding dominant, real-world degradation mechanisms and how to better simulate real world aging in the lab to assist in designing better SCR catalysts.

Reviewer 2:
Finishing the transient reactor and measurements on the field-aged catalysts are major items in the future research. The spatially resolved capillary input mass spectrometer (Spaci-MS) database measurements should be very useful. Bringing results to improving the durability of SCR catalysts would be a highlight for next year, if achieved.

Reviewer 3:
In general, the path for the project is clear. Now that the team and strategy are in place, moving to field aging and varying the catalyst formulation are needed. The presentation mentioned the catalyst formulation will vary in FY 2021. Some general comments on how it will be different (metal content, support, etc.) would have enhanced the picture of the proposed work significantly.

Reviewer 4:
The move to obtaining enough results from field-aged samples to develop and tune the kinetic parameters is the right next step. Will all samples have to be rerun in the new reactor? The reviewer hoped that is not the case. Then the challenge will be determining if those newly measured kinetics help define the real-world aging mechanisms and how to incorporate these into a model. The proposed future work is appropriate.

Reviewer 5:
The reviewer said that future steps are determining the impact of field aging on kinetics of commercial Cu-SSZ-13 SCR catalyst; and determining the kinetic origins of performance for low-temperature formulations. The reviewer asked about the impacts of lube oil and NO_2/NO_x. Both impact the pre-exponentials of the kinetics, and the impact of NO_2 was barely mentioned.

Reviewer 6:
Less effort should be placed on building a new reactor system when that resource should already be available at one of the partner organizations. More timely effort should be placed on dissecting a reference catalyst in terms of linking its performance along its length to the actual condition of the catalyst to predict an overall performance measurement.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project absolutely supports the overall DOE objectives. From the introductory slides and the focus of the research, it is clear the team has carefully considered how the work fits into the greater context of the VTO and DOE goals. The project does an excellent job of fitting into a space between a focus on primarily fundamental topics not applicable to an applied program and being so applied in nature it appears the work is a subcontract

to another specialty company. Construction of the reactor and knowledge gained from the experimental/modeling studies will do the following: certainly benefit the systems of interest with real world potential; simultaneously develop a methodology and approach that might find use in other contexts. As such, the work resides in an excellent niche very suitable for VTO projects.

Reviewer 2:
Reliable and accurate diagnostic methods are highly sought after by OEMs, especially given the future mandates for full useful life of these aftertreatment systems.

Reviewer 3:
With new regulations forthcoming and demanding a significant increase in catalyst lifetime, this work is highly relevant to ensuring the continued use of high efficiency engines.

Reviewer 4:
This work is uniquely relevant to improving our understanding the mechanism of the very important ammonia SCR reaction in HD diesel NO_x aftertreatment.

Reviewer 5:
The development of lab- or engine-based SCR catalyst aging protocols that better simulate real world performance is an important enabler to designing more durable SCR catalysts.

Reviewer 6:
The reviewer affirmed that-SCR means fuel economy, and low-temperature operation means more fuel economy. Both fit DOE's energy policy.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
All resources seem appropriate. As the reviewer mentioned in prior comment, all needed components to finish the project (reactor working, experimental data collection in place, and modeling moving toward the level needed to complete the project goals) are in place.

Reviewer 2:
The resources seem appropriate for the milestones over the project term.

Reviewer 3:
Between Cummins and ORNL there are sufficient resources to characterize these catalysts.

Reviewer 4:
Cummins and ORNL have sufficient resources for this project.

Reviewer 5:
Resources are adequate and modeling resources are strong. Characterization resources are good as well.

Presentation Number: ace033 Presentation Title: Emission Control for Lean Gasoline Engines Principal Investigator: Vitaly Prikhodko (Oak Ridge National Laboratory)

Presenter

Vitaly Prikhodko, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

All reviewers indicated that the project was relevant to current DOE objectives. Two reviewers indicated that the resources were sufficient while the third reviewer indicated that the resources were insufficient.

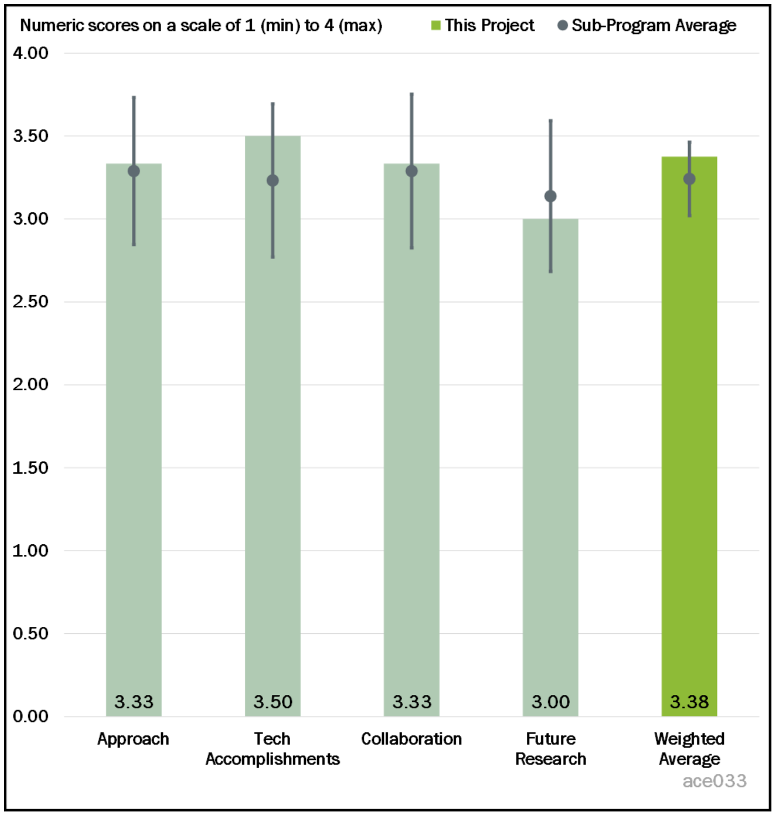

Figure 1-6 - Presentation Number: ace033 Presentation Title: Emission Control for Lean Gasoline Engines Principal Investigator: Vitaly Prikhodko (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The passive SCR strategy is promising to develop lean burn spark ignited (SI) engines with no external reductant tank (urea tank). The use of TWC as an ammonia generator is novel. For this strategy to be efficient it is very important for both engine and catalyst be optimized to work together. The team approach used in this study—focusing on optimizing different parts of the system, mainly engine lean operation, engine rich operation, NO_x-to-ammonia conversion etc.—is an excellent approach to realize the true benefits of this approach. Furthermore, change in the engine platform to a current/future technology engine is a very good change.

Reviewer 2:

This project is a good blend of reactor testing and engine testing. It is commendable that the project team is optimizing the engine and catalyst together as a system. The reviewer especially appreciated the aging studies on the SCR catalyst where the A/F ratio of the exhaust was varied (lean, stoichiometry, or rich). The reviewer is hopeful that the new MAHLE engine will be more amenable to the lean-burn work.

Reviewer 3:

The project is well designed and on track. However, despite its potential benefits, its overall cost to benefit ratio is unclear. Control and on-board diagnostic (OBD) aspects of this architecture are unknown, not studied and probably outside the range of the current study.

Though, from an exploration point of view, this concept is interesting, this technology will have a weak chance in the commercial space as its challenges include:

- "Efficiency, durability," are said to be the targets. However, the system's inherent fuel penalty signals lack of fuel efficiency. The hope is however that this fuel penalty (to form ammonia) is well below lean engine offering 5%–15% increased efficiency (over stoichiometric-operated gasoline engines).
- Increase in carbon dioxide (CO_2), due to excess fuel used, is another challenge of this approach.
- High-temperature NH_3 storage is degraded at 700°C aging and eliminated at 800°C.
- The upstream TWC typically exposes the SCR to higher temperatures, resulting in faster aging of the SCR catalyst, as observed.
- CO control during rich conditions is a challenge.
- Cost ($0.5 million per year), though appearing on the high end, may not even be sufficient to overcome several of these challenges.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer noted that the work is great in terms of investigating the effects of lean, stoichiometric, and rich aging on the SCR catalyst, which are important for lean-burn gasoline applications that can operate lean at low loads but operate at stoichiometric or rich conditions at high loads. Also, there is a very nice comparison of the lean SCR approach (with NH_3 supplied during lean operation) and the passive SCR approach (with NH_3 supplied during rich operation) as a function of the aging temperature and the aging A/F ratio (lean or rich). It clearly showed that rich aging is detrimental for both high-temperature performance and low- temperature performance with the passive SCR approach, while rich aging was detrimental only for the high- temperature performance with the traditional lean SCR approach.

Reviewer 2:
Installing a new MAHLE jet ignition (MJI) engine with full controls, procuring a new dynamometer and evaluating SCR performance on aged production SCR units are notable accomplishments. The reviewer had questions and/or comments on the temperature in a stoichiometric engine during the ammonia generation phase being high. This would reduce the capability of the SCR to adsorb the ammonia. Furthermore, the thermal inertia of the catalyst may also negatively affect ammonia storage during rich to lean operation change and possibly contributing to NO_x slip from passive SCR. Did the team face the issue of high exhaust temperatures? Air injection could help, but ammonia oxidation to NO_x has to be controlled. Is there CFD related work being planned to cool the exhaust before entering the SCR?

Reviewer 3:
Progress is obvious and sensible. However, there are various challenges that this project needs to overcome to make a convincing case, overall. The reviewer referenced earlier comments and stated that the project will need a stronger, broader push across the budget; novel SCR technology; and solutions to its CO emission, cold-start, and fuel penalty concerns for it to be successful.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The involvement of Umicore LLC and GM is an excellent collaboration for accomplishing project goals. It is imperative to have an active catalyst and engine partner to successfully complete work with objectives such as this project. The team has shown good collaborative approach.

Reviewer 2:
There are good collaborations with GM and Umicore.

Reviewer 3:
The broader team includes one major OEM and a Tier 1 catalyst supplier. The PI has also reached across a broader team, integrating them into the project (though at lower level relative to Umicore and GM); the list is too long to name here (Slide 10).

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Although this is an interesting and promising approach for lean burn SI engine platforms, care should be taken so that the exhaust aftertreatment system does not become overly complex. The passenger car industry is different from HD, and complex aftertreatment system and associated diagnostic development could be a major hurdle. In order to bring strategies such as this to the forefront of production, it is imperative that future research be aimed at simplifying the packaging and the control strategy and addressing durability.

Reviewer 2:
There are several tasks planned for the "future" phase. Future work however will not be sufficient to bring this project to any conclusive end, as it will need a larger plan, more resources, and a multi-pronged approach to addressing its underlying challenges.

Reviewer 3:
The combination of higher HC emissions and lower exhaust temperatures during lean operation on the MAHLE engine will be challenging and will require attention. The project needs to explore ways to minimize the CO without resorting to the clean-up catalyst and air injection. Slide 37 showed that the clean-up catalyst (CUC) alone increased the NO_x emissions by oxidizing NH_3, and air injection would make it even worse. It is much better to produce less CO at the engine. The best way to produce less CO during the rich periods is to run less rich. It is possible to run less rich and still make NH_3 over the TWC if there is less O_2 during the rich periods. That can be verified on the project team's laboratory reactor. Perhaps the project team can work with MAHLE to minimize the amount of O_2 during rich operation. If the team had both a direct injection (DI) injector and a port fuel injection (PFI) injector, it could run lean with the DI injector and run rich with the PFI. The PFI injector results in better mixing and therefore less O_2 during rich operation.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Passive SCR strategy is an excellent approach to realize lean burn SI engines with no urea tank. This will directly contribute to SI engines with significantly lower fuel consumption.

Reviewer 2:
The use of lean burn engines can reduce the fuel consumption of gasoline engines by up to 15%, helping satisfy DOE's goal of reducing our dependence on foreign oil. This project is important because it is exploring ways for lean burn engines to satisfy the Tier 3 Bin 3 emission standards.

Reviewer 3:
From a powertrain exploration point of view, the project aligns with the DOE goals. From the point of view of fuel economy and commercial potentials, this project has many challenges that would need to be overcome.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
ORNL, Umicore, and GM have sufficient resources to address any challenges of this study. Newly added dynamometer capability expands their resources for engine testing.

Reviewer 2:
The resources seem sufficient for the time being, as a lot of good data has been generated in this project over the last year.

Reviewer 3:
The project has many challenges. In order for this project to reach a conclusive end, it needs more resources and a more aggressive project plan to address its many challenges, such as faster SCR aging, stronger cold-start investigation, bag-1 impact, fuel penalty, and CO_2 concerns (due to excess fuel use).

Presentation Number: ace056
Presentation Title: Low-Temperature Oxidation
Principal Investigator: Yong Wang (Pacific Northwest National Laboratory)

Presenter

Yong Wang, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

All reviewers indicated that the project was relevant to current DOE objectives and the resources were sufficient.

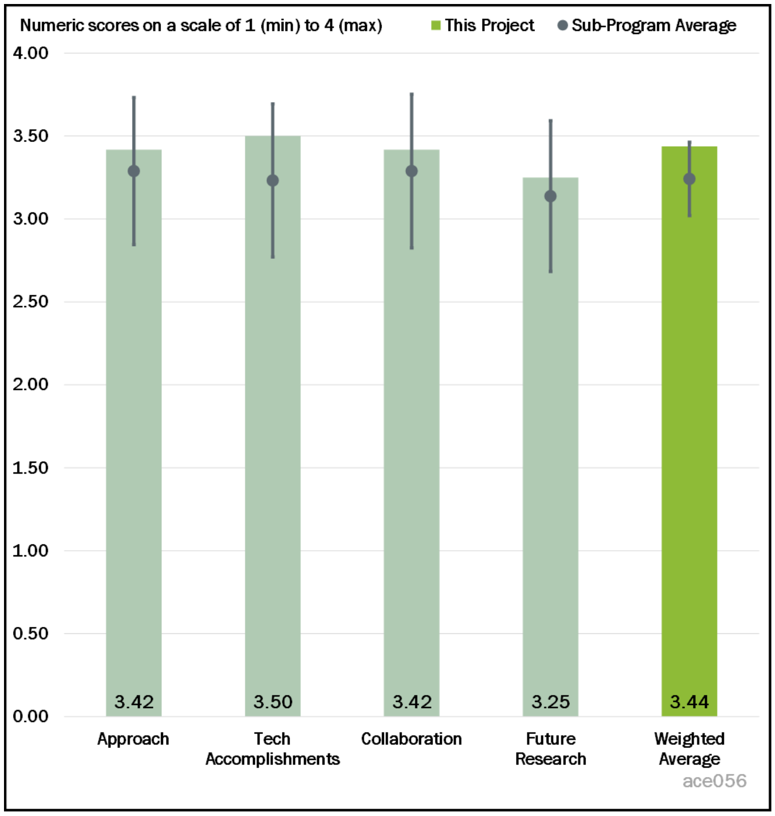

Figure 1-7 - Presentation Number: ace056 Presentation Title: Low-Temperature Oxidation Principal Investigator: Yong Wang (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach to obtaining new knowledge for reducing PGM usage in catalysts and enhancing methane oxidation performance has been excellent.

Reviewer 2:

The work is interesting and incorporates novel approaches. Interim success metrics are met. Project is well designed, and the team is strong. The goals include increasing catalyst activity by atom trapping to create thermally durable Pd single atom catalysts with reduced PGM usage; and demonstrating activity and durability of leading candidate catalyst formulations using U.S. Driving Research and Innovation for Vehicle efficiency and Energy Sustainability (U.S. DRIVE) Low-Temperature Catalyst Test Protocols.

The reviewer commented that successful project demonstration thus far could demonstrate 70% methane conversion at less than 350°C. The next target is achieving 90% or higher methane (CH_4) conversion at less than 350°C. The approach will encompass developing a bimetallic approach using single atom catalysts by atom trapping for methane combustion; and demonstrating a greater than 95% methane conversion at less than 350°C without detrimental effects by sulfur and steam. The reviewer observed a solid project approach to problem solving.

Reviewer 3:

The project intent is to find a CH_4 oxidation active catalyst that will withstand the normal degradation modes. The team studied Pd/SSZ and ceria-based samples. The former was studied in depth, and the team showed problems with atomic (ion exchanged) versus particles as active site, the particles being much more active. These data show single atoms are not appropriate for this reaction in the SSZ material. The identification of particles being active, over the single atoms or ion exchanged species, is noteworthy because so many researchers have focused on single atoms as an answer to thrifting. Pd/ceria and Pd/aluminum oxide (Al_2O_3)

are well known for CH_4 oxidation, and the characterization tools are proving useful in understanding the fundamental catalyst chemistry and the loss in performance over time for these sample types. The team is focused on the right barriers and has demonstrated why those exist.

Reviewer 4:

PNNL is continuing to focus on novel catalyst technologies that offer the potential for greatly improving emissions performance. The development of technologies that significantly increase the dispersion of the precious metal content to achieve greater light-off and sustained catalyst activity is highly desirable to meet super ultra-low emissions vehicle (SULEV) and Tier 3 emissions standards. Although this approach of employing stabilized PGM nano clusters and single atom catalysts is promising, using this technology for CNG catalysts is not of high value to LD vehicle OEMs. There is an overwhelming need for this type of catalyst technology for stoichiometric vehicle use TWCs. Much more benefit would be derived from this work if applied to gasoline stoichiometric applications.

Reviewer 5:

The work contains a published catalyst preparation technique, and the PI used this technique to evaluate CH_4 oxidation reaction. Several catalysts are screened after treating at different pre-treatment conditions. However, narrowing it down to one or two formulations and comprehensively studying those catalysts—rather than screening all pre-treatment conditions and adding more Pd, etc., for all catalysts—would have been a better approach to gain through fundamental as well as potential technical viability of the catalysts.

The project team indicated the performance target, but no cost target (or Pd amount decrease target compared to a selected baseline) was estimated or provided. Having such estimated targets would provide quantitative technical barriers and make it easy to track the progress of the project by analyzing to what degree such barriers were addressed. Therefore, the reviewer requested that the project team coordinate with the catalyst manufacturer JM, who is also a partner, to come up with such estimates and project measures.

Reviewer 6:

The presentation and project identify key technical barriers and provide strategies which attempt to mitigate the majority of issues in the area of low-T methane oxidation. The majority of the project is complete but seems to have made significant contributions to understanding of these catalysts, experimentally characterizing the materials, and getting close to milestone targets of methane conversion.

A few points for longer term consideration: while the Pd focus on the short term seems appropriate, insights into use of other more abundant metals as parts of formulations (as catalysts, supports, co-additives, etc.) appear critical. The lack of modeling, given the relative size of these systems, seems like a missed opportunity, especially with the PI's connection to the PNNL complex.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

As the reviewer previously noted, the successful demonstration thus far shows a greater than 70% methane conversion at less than 350°C (Go/No Go, Slide 7). The next targets are achieving 90+% CH_4 conversion at less than 350°C. The measured accomplishments are noteworthy.

Reviewer 2:

The project seems on track to reach target milestones, which is impressive regarding methane conversion levels. The project team has well characterized systems and has utilized multi-modal techniques well suited to detail location and oxidation state of the metals. The team seemed to address most concerns from a prior review adequately.

The team has published a nice number of papers in high impact journals. Differentiation of the intellectual merit of these more applied projects from those funded by fundamental science programs is key and should continue to be monitored.

Reviewer 3:
The demonstration that nano-palladiums (NPs) of Pd is superior to the performance of single-atom catalysts (SACs) is very important. The excellent stoichiometric activity of Pd added to SACs of rhodium (Rh) is very interesting. Unfortunately, recent price increases for these two metals make them PGM choices one may want to improve upon. The understanding of the deactivation of Pd NPs by alumina is a very well-done piece of work.

Reviewer 4:
The novel catalysts proposed in this work offer twin benefits of reduced cost and greater performance. However, ensuring that catalysts are compared on an equal basis in terms of thermal and chemical aging is important for determining their true benefits. Aging conditions and results should be made clearer. Also, increased conversion efficiency resulting from the addition of more PGM is not unexpected. Quantifying that effect better to optimize the use of Pd and Rh would provide greater insight into whether or not the additional PGM is simply additive or if there is a synergistic benefit between Pd and Rh. In either case, it should be noted that this is a very novel area of development that appears viable for OEMs.

Reviewer 5:
The goal of achieving lower temperature activity in unaged materials was met. The question is whether those samples (i.e., Rh/Pd/ceric oxide [CeO_2]) can withstand degradation modes. The characterization tools show interesting results that helped guide their conclusions. The thrifting aspect remains elusive; with the addition of Pd to a Rh catalyst, this goal seems challenging. The active site identification is an important result, but what will be done with it does not seem obvious. The continued use of ceria as a support seems to be problematic, but the next steps (degradation studies) will prove or disprove this intuition.

Reviewer 6:
Even though it seems the technical targets can be potentially approachable from the test done so far, a couple of comparisons were lacking, and such comparisons should not take significant resources and time to generate. It is not obvious how the base line technology performs. As a well-known supplier is part of this project, the reviewer suggested comparing (minimal work) one or two baseline technologies relevant to the ACE056 project. From such baselines it is also possible to compare PGM reduction targets; it is not expected to take significant resources to expose the catalyst to, for example sulfur, and carry out the tests. Such tests are expected to be very limited and that would give insights into the gaps in achieving the technical targets.

There are several remaining challenges and barriers proposed by the PI. In fact, these barriers are most critical for generating fundamental understanding of potentially viable technology that will be evaluated in the rest of this year. It appears that, in order to comprehensively evaluate all the suggested workflows, it will take significant resources and time. It is suggested that the critical challenges must be prioritized and comprehensively evaluated rather than evaluating all the factors superficially. Such an approach will be useful in developing deep technical insights and the potential for successfully developing a viable technology.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
It appeared to the reviewer that the collaborative groups are excellent.

Reviewer 2:
The team includes PNNL scientists and labs, one major OEM, and a key Tier 1 supplier. Collaboration appears established and strong.

Reviewer 3:
There is obvious collaboration with ORNL via the synthesis and protocol discussions and exchange. JM's role in baseline catalyst supply is met. GM's role in guiding relevance is appreciable.

Reviewer 4:
The inclusion of an OEM and catalyst supplier in this work to help develop the technology and guide the direction of the work is highly desirable. However, GM is not a major user of compressed natural gas (CNG) technology for its vehicle fleet.

Reviewer 5:
The contributions, other than consulting, from GM and JM are not obvious. The questions raised in approach and technical accomplishments need their significant contributions, and the reviewer requested that the PI include them if possible and also make specific contributions more visible in the presentation.

Reviewer 6:
The slides and presentation could have done a better job delineating who did what, i.e. what were the specific contributions spread across the various partners. The reviewer is familiar with many of the involved participants, but this would not be clear to someone less versed in the science of these researchers. A separate slide showing a discrete example of how the team worked together on each component of the work would have been powerful in convincing reviewers the project team provides a sum greater than the parts.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Success for the end goal (CH_4 oxidation in low temperature) has been divided into achieving it at approximately 70% first and 90+% next. This is a rational approach and appears to be a successful strategy.

Reviewer 2:
The proposed challenges to overcome are reasonable and very appropriate for ensuring that this catalyst technology will be viable for the intended application. Thermal and chemical durability is even more important now to the OEMs due to the onset of Tier 3 and SULEV emissions standards.

Reviewer 3:
The proposed embedding of Pd in a hydrophobic zeolite in the last year of the project seems ambitious, given that it will then need to be characterized, tested, and exposed to the degradation criteria. It will replace the ceria as the support, which should be helpful for degradation. But, t this seems rather ambitious in a last year, especially since the degradation aspects have to be addressed for the other materials also.

The reviewer commented that the thrifting seems to be going the wrong direction over the last year – the addition of 3% Pd to an Rh-containing catalyst seems costly.

Reviewer 4:
The presentation could provide more information regarding the state-of-the-art in Pd embedded in hydrophobic zeolites and the silica materials. Is the hydrophobicity tuned enough as a parameter to justify exploring these materials? Could the coating lead to deactivation of the catalyst? No results were shown to demonstrate otherwise.

Silica porosity (or lack thereof) may create significant issues that were unaccounted for in the presented materials. It seems a bit dubious to this reviewer that all these material types could be screened for activity in the reminder of the project.

Reviewer 5:
Technical challenges still remain for these catalysts. The reviewer indicated that it is very challenging to deal with the deactivation in water and with sulfur. The support change looks promising.

Reviewer 6:
There are several remaining challenges and barriers proposed by the PI. The reviewer assumed they will be evaluated in the rest of this year. It also appears that comprehensively evaluating the suggested workflows will take significant resources and time. It is suggested that the critical challenges must be prioritized and comprehensively evaluated rather than evaluating all the factors superficially. Such an approach will be useful in developing deep technical insights and the potential for successfully developing a viable technology.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer's response was absolutely. From the introductory slides and the focus of the research, it is clear the team has carefully considered how the work fits into the greater context of VTO/DOE goals. In addition, the applications of the PIs developed catalysts could clearly extend to a range of reactions of VTO interest.

Reviewer 2:
Enabling low-temperature CH_4 oxidation, an enabler of natural gas engine technologies, appears aligned with DOE objectives.

Reviewer 3:
Improved catalysts in this area at low temperatures will lead to more efficient emissions control.

Reviewer 4:
This project supports the valorization of CH_4 for transportation applications. Low cost, but highly active aftertreatment catalysts would enable natural gas vehicle use. The standout issue is the choice of catalysts, with ceria as the support and the addition of Rh as a metal. Admittedly, the project team did learn about SSZ supported oxidation catalysts—which people have been proposing–and the team's work provides better focus for those.

Reviewer 5:
Tier 3 and SULEV20/30 enabling catalyst technologies that are cost effective and durable are very appropriate going forward.

Reviewer 6:
Methane oxidation, under both lean and stoichiometry conditions, is difficult, and the existing technologies are expensive and only work at high temperatures. This could limit, for example, applications of some engine and fuel options, such as dual fuel. Similarly, the cost of Pd might prohibit the widespread usage of NG engines that can decrease CO_2 emissions as well as make United States less dependent on oil.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project resources appear to be sufficient for ensuring a positive outcome for the development work.

Reviewer 2:
This project is an undertaking at the fundamental catalysis stage. Its execution at and with the PNNL catalysis lab/team reflects its state-of-the-art resource access.

Reviewer 3:
All resources seem appropriate. All needed components to finish the project are in place.

Reviewer 4:
The resources seem appropriate for the milestones over the project term.

Reviewer 5:
It appeared to the reviewer that there are sufficient testing capabilities available at PNNL and ORNL.

Reviewer 6:
The PI and partners have all the right reactor and advanced characterization resources as well as catalyst supplier resources to address the milestones in timely fashion.

Presentation Number: ace085
Presentation Title: Low-Temperature Emission Control to Enable Fuel-Efficient Engine Commercialization
Principal Investigator: Todd Toops (Oak Ridge National Laboratory)

Presenter

Todd Toops, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

All reviewers indicated that the project was relevant to current DOE objectives the resources were sufficient.

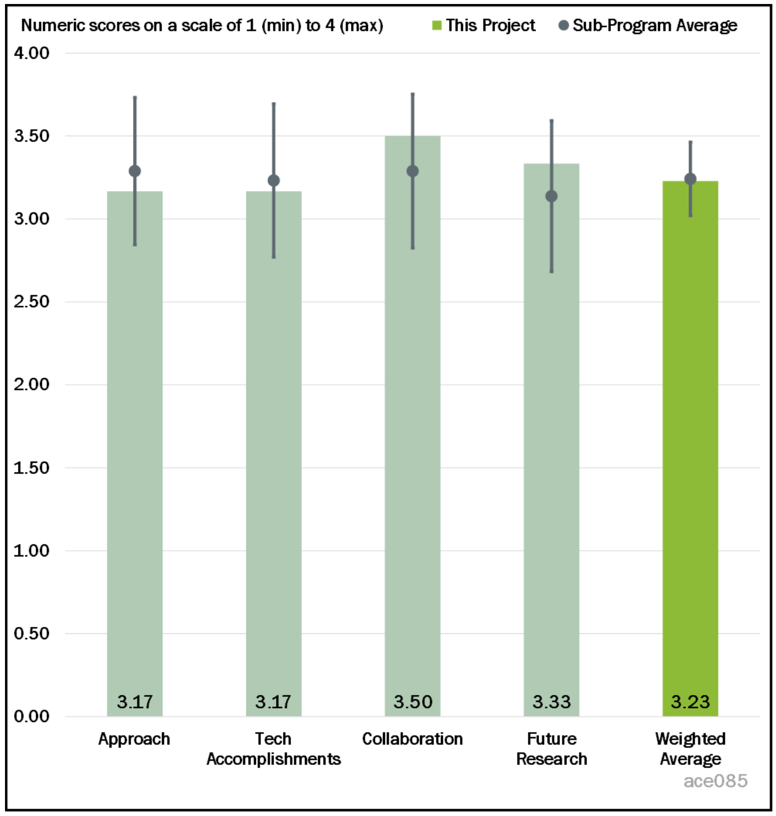

Figure 1-8 - Presentation Number: ace085 Presentation Title: Low-Temperature Emission Control to Enable Fuel-Efficient Engine Commercialization Principal Investigator: Todd Toops (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Theis, Joseph

The ACEC testing protocols have been used in evaluating low-temperature catalysts. For the PNA work, multiple sequential tests have been performed to investigate the deactivation of the PNA with different reductants. This is very important, as the gradual deactivation of low-temperature NOx adsorbers (LTNAs) during repeated cold-start tests is currently the biggest issue for the technology. This must be solved before PNAs can ever be considered for vehicle applications.

Reviewer 1:

The project had adequately addressed its two main goals of low-temperature conversion and reduced PGM loading (Metalmark, etc.).

Reviewer 2:

A variety of catalytic systems has been researched for various engine platforms. This study is the culmination of different research projects carried out by ORNL. However, as a study that compiles the results of many research works, it should also critically assess the needs of the industry and the technical viability of the solution. For example, the lean spark ignition (SI) and conventional diesel combustion (CDC) solutions seem to be overly complex.

Multiple aftertreatment systems are probably required but does the work address innovative approaches of packaging five different catalytic systems under a vehicle body? It is very important to be cognizant of the packaging challenges of multiple catalysts in a vehicle. While conducting controlled studies on separate units help provide clarity, approaches—zone coating two different catalysts, a catalyzed gasoline particulate filter (GPF), etc.—should be considered, if they have not been already.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
There is good work in assessing the deactivation of the Pd/SSZ-13 PNA with and without reductants. The results are very consistent with the work reported by Ford, in that CO causes the deactivation while HC, hydrogen (H_2), and NO_x do not. Impressive amounts of data have been reported on the core-shell catalysts with Pd and/or platinum (Pt).

Reviewer 2:
One task has been complete during this period and two tasks are on track. FY 2020 and FY 2021 milestones are critical.

Reviewer 3:
The reviewer stated that it is fair to rank the accomplishments as "work in progress" since the project just finished its first year, is in mid-stage, and hence has one more full year of investigation to complete. In all, the project appears on track. It is ranked overall as "Good" because no major, "internal" pathway for lowering PGM appears to have been taken. Given the capabilities, resources, and close collaboration with PNNL, one wonders why such a path was not considered. After several years (more than a decade) of coaters talking about PGM reduction, it is fair to say this (lowering PGM) is something that most likely the coaters will not invest a major effort on, and that ultimately the National Laboratories (the government) and/or the smaller, private labs would need to make that happen.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The team involved in this project is extensive, and the progress shows excellent contribution from different team members.

Reviewer 2:
Good collaborations with the University of Buffalo, Harvard University, Chalmers University, the University of Virginia, and PNNL.

Reviewer 3:
Collaboration with the University of Buffalo team and a broader, internal team at ORNL is integrated into the project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Future stages are planned well and clearly defined across materials, PGM reduction, and low-temperature performance.

Reviewer 2:
It was good to see that the project team is exploring other zeolites (LTA) for the PNA work as well as co-cations that could potentially re-oxidize the Pd that is reduced during testing and thereby decreases the degradation observed during repeated NO_x storage and release testing. The reviewer would encourage the project team to continue exploring catalyst formulation changes (zeolites and/or metals) as well as systems modifications (e.g., catalyst zoning, layering) that might decrease the degradation. The team might consider reducing the maximum temperature of the temperature ramps from 600°C to 400°C, or even 300°C, as these are more realistic maximum temperatures on diesel engines during normal operation. For the core-shell work,

the team needs to assess the OSC of the catalysts and implement A/F dithering during the light-off testing to simulate actual vehicle operation. It would be interesting to poison the core-shell and non-core-shell samples with S and P to see if the core-shell catalysts are more robust to the poisons. Lower PGM loadings are also important to explore. While the protocols call for aging at 800°C, the team might also age some samples at 900°C if the catalyst is intended to function as a TWC.

Reviewer 3:
Future research should be more aimed at addressing the simplification of the proposed aftertreatment solutions. For the industry to accept the outcomes of this research it is imperative that it is production viable and cost-effective in manufacturing, installation, and durability.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The development of low-temperature catalysts is critical for meeting stringent emission standards on fuel-efficient engines that generate lower exhaust temperatures. These engines can reduce the fuel consumption of vehicles and thereby satisfy the DOE objective of reducing our dependence on foreign oil.

Reviewer 2:
Yes, the project does support DOE objects on several grounds, which include lower temperature activity (enables fuel savings) and PGM reduction (economic impact on the mobility industry).

Reviewer 3:
Overall, this project is aimed at supporting the emissions control system of future high-efficiency engines. This supports the overall objectives of DOE

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
All the team members are highly experienced and well equipped with resources to address all project milestones.

Reviewer 2:
The reviewer affirmed resources appear sufficient.

Reviewer 3:
The reviewer stated that the resources seem sufficient for now, although additional testing resources could be needed to explore different PNA formulations with different zeolites and/or active metals. Additional testing resources might also be needed to test TWCs and core-shell catalysts with A/F dithering. Extra resources might also be required to explore reduced PGM loadings.

Presentation Number: ace100
Presentation Title: Improving Transportation Efficiency through Integrated Vehicle, Engine, and Powertrain Research - SuperTruck 2
Principal Investigator: Darek Villeneuve (Daimler Trucks North America)

Presenter

Darek Villeneuve, Daimler Trucks North America; Jeffrey Girbach, Daimler Trucks North America

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 86% of reviewers indicated that the resources were sufficient, 14% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

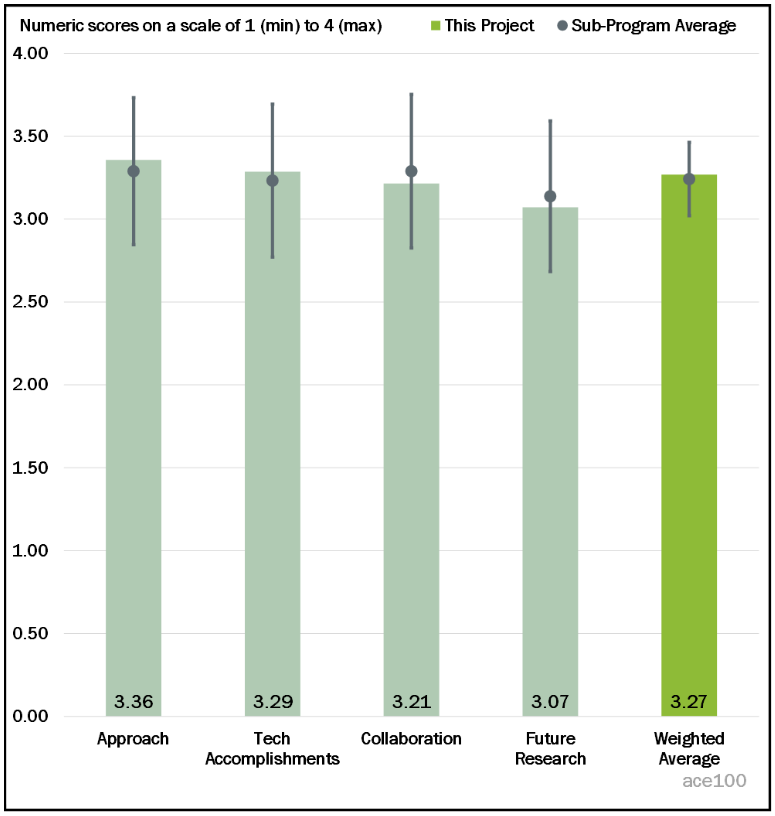

Figure 1-9 - Presentation Number: ace100 Presentation Title: Improving Transportation Efficiency through Integrated Vehicle, Engine, and Powertrain Research - SuperTruck 2 Principal Investigator: Darek Villeneuve (Daimler Trucks North America)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project team's use of strategies that can carry over into production such as the friction reducing coatings are spot-on targets for the industry.

Reviewer 2:

There is a good, multi-pronged approach to find every possible source of energy savings. The honesty expressing the commercial viability being about 2% of the aerodynamic savings is very much appreciated.

Reviewer 3:

The approaches taken for both engine and vehicle are technically sound and supported by aggressive technologies developed for this program. Taking the engine as an example, it includes phase-change cooling (PCC)-type of waste-heat recovery (WHR) and two-stage turbochargers; advanced air system with two-stage exhaust gas recirculation (EGR) cooling; and friction and parasitics, etc., which would make the program likely to achieve the program goals.

Reviewer 4:

The project is on path to making decisions to meet the goals. The reviewer appreciated that this team has a "commercialization committee" that is helping direct the team on technologies that fleets really want to buy. It shared a few examples of where technologies were taken out of their plans via this process—well done. It is actually shown as red on the waterfall chart. The project seems on track with the approach.

Reviewer 5:
The approach to achieving the SuperTruck 2 goals is solid; most of the technologies under consideration are either well developed or at least widely studied approaches in the R&D community. This gives a high degree of confidence in the potential for meeting the 115% fuel efficiency (FE) goal of the program. The reviewer was unsure, based on the results and projections shown, if the 55% brake thermal efficiency (BTE) goal will be easily achieved; the reliance on the phase change waste-heat recovery (WHR) system with all of the development required at the casting level as well as with high performance WHR equipment is risky. That said, the reviewer was not sure that there are too many other options beyond what is currently being pursued and this will be a common challenge of the SuperTruck 2 program. The other engine technologies under development are reasonable approaches, and it looks likely that a 50+% BTE will be achieved without WHR.

Reviewer 6:
The technical approach to system-level performance improvement is on track to exceeding the funding opportunity announcement (FOA) goals based on the 2009 baseline comparison vehicle. The team also established significant progress over a more relevant model year (MY) 2017 production Cascadia, but the reviewer would have liked to see a comparison to a current model year production tractor to better gauge the commercial viability of the technologies. The team identified only briefly technologies that were not viable in scope of the project objectives. Optimizing tire coefficient of rolling resistance (C_{rr}) differently between tag and pusher tires did not consider total cost of ownership (TCO) ramifications to fleet operations and replacement rates, retreading, etc. The project has significant software integration elements that were not discussed and may impact the schedule for the final, fully integrated vehicle road testing. Delay of engine delivery for the demonstrator will pressure software integration activities. There was little or no discussion of trailer and trailer partner efforts in the project, yet significant savings were identified in the FE plan. There was also no discussion of trailer tire C_{rr} improvement.

Reviewer 7:
The approach taken by Daimler covers a reasonable arrangement of technologies. The selection of 48 volt (V) for mild hybridization is seen as a good compromise. The Slide 4 figure and indicated freight efficiency numbers are a bit unclear, specifically the red marker under Tractor Aero.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Accomplishments are significant against objectives, and this team did a very good job of presenting them to the reviewers and overall audience.

Reviewer 2:
There has been good progress in the past year, and it looks like all the parts of the program are on target for finishing up the work on schedule. The reviewer saw that there are some delays due to COVID-19, but that is common across all of the DOE programs, so the reviewer was not too concerned about that. In general, the measured results that were shown are consistent with what the reviewer would expect for the technologies presented, and they look promising. The reviewer would have some concerns about the additive benefits of some of the technologies since those do not always show up when the final engine is built, but the overall results look good.

Reviewer 3:
The technical accomplishments to date are significant, showing good progress toward FOA goals. The development and testing of the development truck demonstrate progress at the component and subsystem levels; however, the demonstrator build will identify integration issues that the development truck did not

explore. The integration of predictive cruise control and adaptive cruise controls was touched on briefly. There are significant operational ramifications to fuel economy in traffic conditions that may limit the benefit of these features. Data on the potential opportunity in a variety of real-world traffic conditions and variety of driver skill levels should be discussed. Very little was presented on commercial viability of the technologies within the FOA recommended time spans. The PCC WHR approach is innovative. A discussion of the cost effectiveness of this approach with respect to operational maintenance, reliability, and warranty is required with respect to FOA goals of commercial viability.

Reviewer 4:
Development procedures for aerodynamic and engine performance appear to be solid, industry-best methodologies to seek gains that are usable for validation without wild R&D risks. The test miles and other test feedback are a strong indicator of progress.

Reviewer 5:
On the engine side, achieving 52.9 % BTE is a great accomplishment at this stage. With fine tuning on all packages, it sounds like t this project has an excellent chance to meet the program goal. The technical achievements on the chassis development side are impressive, with the quantitative improvements on tires. It would be even more impressive if the similar quantitative improvements can be demonstrated in the aerodynamic and exterior development and energy management.

Reviewer 6:
The technical review covers a wide range of items in only a few pages. Some of the materials presented fail to have sufficient description to allow the reviewer to understand the impact or merit of the technology presented. This is the case for the bumper duct optimization (What are we looking at?), the delta drag coefficient (Cd) (What is x?), and cooling drag (What is the color scale? What criteria are being followed?) on slide 5. Slide 6 shows a skeleton of the air system, which appears incomplete and incorrect; the charge cooler on the engine and on the radiator pack are not linked up. What is the boost recuperation shown on Slide 7? Unfortunately, most of the material presented suffers from a similar lack of information.

Reviewer 7:
The reviewer was not sure that the same honesty seen in the aerodynamic commercialization was seen in the friction reduction attributed to the friction reducing coatings. The statement “Friction hardware shows significant improvements in brake-specific fuel consumption (BSFC) over stock hardware” implies it will be a big part of the final demonstrator package, but the data shown are a combined effect of these coatings, along with lower viscosity oil, thus a lower pumping loss. With no numbers on the graph, the reviewer had doubts that the benefit will be worth the cost and risk involved with these coatings (long-term durability and effect on oil consumption).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
It looks like the work package has been split up across the team and that everyone is working well together to validate the technical paths. The vehicle work shows good technology transfer back to Daimler, and as the engine work moves toward the final build, the plans also look good for technology transfer.

Reviewer 2:
Evidence of teamwork shows on many different slides and areas. Given their fleet inputs from Schneider and the fact that Schneider heads up the North American Council for Freight Efficiency (NACFE), this would seem to be a team with fleet results in mind.

Reviewer 3:
Some of the project partners’ work is provided (e.g., Michelin tires, Oak Ridge friction reduction, and NREL battery package). But details as to the other partner’s work is not covered here.

Reviewer 4:
There is nice identification of the collaborators on the upper right of the Powertrain section. This really helps understand how the partners are contributing. However, this did not seem to be the case in the Vehicle section. Please consider doing this for the whole project, as it makes the review easier.

Reviewer 5:
The project team includes a cross section of expertise as desired in the FOA. Input from the fleet and trailer manufacturer team members was not significantly discussed in the presentation. The tire representative participation seems focused on the tractor tires only and there was no discussion on fleet partner tire replacement cycle ramifications. Fleet perspectives on service and operator training and maintenance and reliability of the overall systems were also largely missing from the presentation, all relevant to commercial viability as requested in the FOA.

Reviewer 6:
Project partners are significant, but the reviewer would have appreciated more recognition of their contributions in the slides and/or the presentation. Where exactly did they help in making critical decisions on the project? The reviewer suggested that a few examples would have really helped.

Reviewer 7:
Although it would be impossible to make so much progress without collaboration, the entire presentation does not give the reviewer any sense of how other team partners help the program. Without any sort of acknowledgments—even with the logo of each company or partners throughout the presentation where they are applied—it makes the project look incomplete.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The plans moving forward look good; the team is entering the part of the project where all of the individual developments get put together into the final builds, and those plans all look solid and achievable.

Reviewer 2:
This team appears to be in the build-and-validate mode with minimal remaining research compared to the other teams.

Reviewer 3:
Moving to the final demonstrator truck and barring any COVID delays, the project will be on schedule.

Reviewer 4:
The project presented a competent plan for addressing COVID-19 related schedule impacts but did not discuss cost ramifications to project funding. Risk mitigation prior to COVID-19 impacts appeared to be well executed with identification and evaluation of competing approaches to technologies. The delay in engine delivery has cascading impacts to multiple systems in terms of validating operations, and this domino effect has not been quantified in any detail. For example, schedule delays could impact expediting costs for purchases, premiums for testing windows, extension of staff labor commitments for system support, etc. The reviewer would have liked to see a discussion of demonstrator testing in concert with MY 2021 production tractor and trailer to properly benchmark program potential versus the latest real-world truck technologies, a step that project management will likely be doing anyway to gauge commercialization potential. Delays in the demonstration program also may impact applicability of any of the technologies being adapted for use to aid in meeting planned future U.S. Environmental Protection Agency (EPA), Air Resources Board (ARB) and other emissions requirements.

Reviewer 5:
The team seems to know the areas of concern for the schedule to complete tasks. Virus corrections will be critical to not seeing significant delays.

Reviewer 6:
The future proposed work chart on Slide 18 focuses on the vehicle, and no mention is made on the engine activities.

Reviewer 7:
Using a very busy project timeline slide with a little or no explanation on the future research dilutes the achievement of this project. Therefore, it would be helpful if one designated slide with the detailed explanation on the proposed future research can be used.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project very well supports the overall DOE objectives because of 55% BTE goal on the engine side and 125% improvement on the vehicle side.

Reviewer 2:
This project directly meets the VTO programmatic goals for high efficiency freight technology demonstration.

Reviewer 3:
HD tractors are such a large contributor to greenhouse gas emissions that ongoing projects in this area are very important.

Reviewer 4:
The reviewer found this team to be advancing the current state of the art without being risky with technologies that do not feel like R&D-only efforts. If many of these items can be put into production in the next 5 to 10 years, the industry will gain from how these tax dollars have been invested.

Reviewer 5:
It appeared to the reviewer that work is relevant. Some indication on cost-benefit should have been given.

Reviewer 6:
Improving heavy-duty transport efficiency is a critical need both in terms of satisfying future CO_2 regulations and for addressing DOE’s broader goals of energy independence, improved efficiency, and greenhouse gas (GHG) reduction. This project should develop key technical solutions to achieve these goals.

Reviewer 7:
The project relevance focuses on key technologies such as electrification of accessories through the use of 48 V systems, incorporation of waste heat recovery technologies, lightweighting, improved aerodynamics, improved tire rolling resistance, improved lubricants and coatings, improved driver assistance with predictive cruise control (PCC) and adaptive cruise control (ACC) systems, etc. What appears to be missing seemed to be significant discussion of the commercial viability of these choices and any discussion of applicability to expanding market volumes and future proofing tractor technologies such as applicability of the 48 V accessory systems to battery electric, fuel cell electric, and other alternative fuel vehicles also in work at Daimler, its subsidiaries, and partners.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project team has all it needs to accomplish the program goals.

Reviewer 2:
The budget and spend rate look good in terms of the project scope and achievements.

Reviewer 3:
It appeared to the reviewer that the resources for this project seem just right. It looks like there has been an increase in cost sharing put in by Daimler, so this project is showing very good leveraging of DOE funds.

Reviewer 4:
The reviewer said that the resources for this project seem sufficient.

Reviewer 5:
It seemed to the reviewer that the resources appear adequate.

Reviewer 6:
The reviewer is slightly concerned about the COVID-19 3-month delay, but it is understandable in these challenging times. Hopefully, the team continuity is not lost as dollars are focused elsewhere for a while.

Reviewer 7:
The project showed that the 2019 budget summary for both the engine and vehicle efforts exceeded the planned budgets by approximately $3.1 million and reporting 70% project completion to date. The 2019 Annual Merit Review (AMR) showed underrunning budget by approximately $2.2 million with 50% complete. The 2018 AMR showed underrunning by approximately $0.3 million with 30% complete. The 2017 AMR showed 5% complete and program budget with no spend to date shown. For 2020, the project did not report any significant budget issues with respect to the COVID-19 schedule and manpower delays but did report there were delays. Carrying manpower longer in years 2020- 2022 than originally planned may increase budget pressure that appears to be somewhat overspent as of the 2020 AMR reporting, considering prior year reports. Any expediting of work may also pressure the budget. Insufficient information was provided in the review to determine the extent of remaining approved funding.

Presentation Number: ace101 Presentation Title: Volvo SuperTruck 2: Pathway to Cost-Effective Commercialized Freight Efficiency Principal Investigator: Pascal Amar (Volvo Trucks North America)

Presenter

Pascal Amar, Volvo Trucks North America

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 86% of reviewers indicated that the resources were sufficient, 14% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

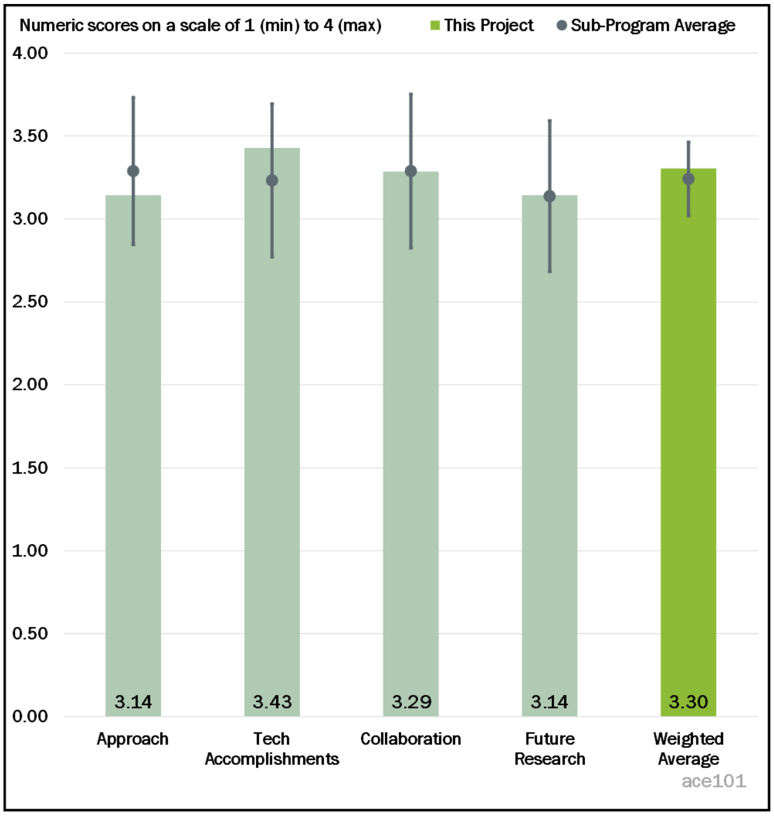

Figure 1-10 - Presentation Number: ace101 Presentation Title: Volvo SuperTruck 2: Pathway to Cost-Effective Commercialized Freight Efficiency

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach taken by Volvo is well coordinated and clearly indicated in this presentation. The presentation summarizes the concept-technologies grouped in vehicle and powertrain groups with what appears a comprehensive system integration. Volvo's partnership with NACFE gives a channel for the voice of the customer and assessment for adoption of the technology.

Reviewer 2:

The tractor-trailer pairing modeling adds a unique perspective on optimizing this configuration as a function of the freight route. This is an additional, and unique, way to get real-world efficiency by taking operator and fleet manager input into account.

Reviewer 3:

The reviewer liked the approach of this OEM to design specifically for a growing segment of more regional operations and having a focused specification to maximize the opportunities for technologies. This creates a focused truck for a pretty large population of trucks. Waterfall charts are helpful to communicate progress against efficiency goals.

Reviewer 4:

The project is really nice in the way it has taken a holistic view of the question of freight efficiency. Since it is widely understood that most trucks cube out rather than weigh out, allowing a 65,000 pound (lb) gross vehicle weight (GVW) limit opens up some interesting optimizations for the truck. That does beg for comparison with the other SuperTruck teams. Everyone is targeting the freight efficiency gain at 65,000 lb GVW per the project requirements, but most of the other trucks look capable of 80,000 lb GVW (at least in principle). The reviewer thought the approach taken here is quite justifiable, but it may lead to a demonstration truck that is not particularly market attractive. Will fleet customers accept a truck that cannot achieve 80,000 lb GVW? If not, how much of what has been done here transfers over to a sellable truck?

The reviewer also had mixed thoughts on some of the technical accomplishments. The generative design work is really interesting and clearly leads to a well-optimized physical design to balance weight and structural requirements. But, how do these parts look in terms of production feasibility? That was supposed to be an important part of SuperTruck 2 so that there could be good technology transfer. Will some of these kinds of technologies be able to be brought to market at a competitive cost? The reviewer also was left with some questions on the engine walk to 55%. The individual results that were reported on showed efficiency gains in line with what the reviewer would have expected. But, in the efficiency walk, there is a path shown to 54% BTE based on the technologies developed and then a bar showing a jump to more than 55% that appears to be based on the efficiency delta between the 11-liter (L) and 13-L engines. Does this mean that the 55% engine will be a 13-L engine and the truck engine will be an 11 L? Are all of the technologies applicable to both engines if so?

Reviewer 5:

The project is well designed for addressing technical barriers and establishing technical feasibility, but details presented for commercial viability requested in the FOA were minimal. Of particular concern is optimizing the vehicle for a maximum vehicle weight of 65,000 lb when the baseline 2009 FOA vehicle is to be capable of 80,000 lb gross vehicle weight rating (GVWR). While optimizing for 65,000 lbs was explained as a project choice, and the team plans option content to make 80,000 lb GVWR feasible, the comparison to the baseline is an apples-to-oranges comparison. The target weight of 65,000 lb GVWR in the FOA was based on average loads seen in commercial vehicles; however, that can mean that a specific tractor sees weights above and below that average during the course of operations. Data were not presented as to the number of vehicles that actually operate consistently below 65,000 lb GVWR as opposed to just averaging 65,000 lb GVWR. The team presented significant progress in trailer weight reduction to assist in tractor-trailer system weight management from the addition of new technologies, such as WHR. The use of generative design optimization tools to refine weight reduction while ensuring structural integrity for engine brackets is an excellent risk reduction methodology demonstrated by the project. Evaluating alternatives sufficiently was also well demonstrated with the 710-millimeter (mm) fan selection methodology.

Reviewer 6:

It seems that the approaches taken for both engine and vehicle have all the essential and aggressive technologies to make sure that the project is able to achieve the program goal. However, the reviewer was not convinced why a 4x2 axle setting for this truck was chosen. Although 4x2 can have benefits with less weight, the issue would be the traction and the load distribution, which may make this truck unrealistic in terms of market acceptance for class 8 truck market.

Reviewer 7:

Although the project team clearly stated that 70% of truck trips are at 65,000 pounds or less, the reviewer was not comfortable that designing a vehicle with that in mind is a proper strategy. Many fleets have loads above that level and are not in a position to have a group of trucks for heavy loads and a different set of trucks for average and lighter loads. Furthermore, the secondary markets for trucks can have wildly different applications and needs from the original purchasing fleets.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

There has been clear progress across pretty much all the components of the program. The work rate leaves no concerns about completing the overall program on time. The path to 115% FE improvement looks clear, with only some uncertainty in the reviewer's mind about the path to 55% BTE based on the efficiency walk and the delta between the 11-L engine with the technology package and the 55% target.

Reviewer 2:
The presentation is well organized and can be followed. This is the case for weight reduction and the cooling package. Freight efficiency building blocks are well summarized although the summary on Slide 10 does not show the WHR segment. The powertrain electrification is well documented. The advanced combustion shows Miller cam and points to reduced cylinder pressure as a gain, although the project team earlier pointed at capability to operate at 250 bar.

Reviewer 3:
The project team demonstrated significant progress toward meeting the FOA technical goals. The project showed limited progress in evaluating potential commercialization toward the FOA project objectives. Progress in employing 48 V systems was significant, as was parasitic loss reduction, including innovations with the variable oil pump. While the attention to lightweighting effectively increased the freight-ton efficiency of the system—such that a 65,000 lb GVWR vehicle effectively carried the same amount of freight as a current 72,000 lb GVWR one—the optimization of the frame and systems for 65,000 lb may not suffice for a vehicle capable of 80,000 lb GVWR, requiring additional structure and added tare weight.

Reviewer 4:
The presentation indicated light on actual numbers and facts and more marketing oriented. That said, the tractor-trailer visually is a thing of future beauty. Methodologies such as the generative design look to have huge potential to optimize future vehicles for weight and reliability. The reviewer loved the simplicity and dual purpose of an air tank designed into a cross-member for packaging and weight reduction gains.

Reviewer 5:
Accomplishments across the various systems are evident and strong for the timing of the project. The team is committed to making aggressive but realistic decisions. There is not enough evidence of commercialization decisions involved here.

Reviewer 6:
The reviewer noted really good achievements in weight reduction that is uniquely done with the generative design. It will be great to see road test validation in next year's presentation. The reviewer articulated that there are a lot of pieces to bring together.

It was clear that the 55% BTE engine demonstration had not been completed yet as it is scheduled for the last year of the project. Slide 13 says that the performance verification is complete, but the summary slide indicates that "Development work continues for the technologies selected to achieve the 55% BTE engine goal." The reviewer did not understand what development work remained. The timeline shows that the concept had been selected last year. This is confusing to understand exactly where the team is on this.

Reviewer 7:
Although the project does provide some incremental improvements of various technologies related to advanced combustion, the reviewer still has no idea what the status is in terms of the overall BTE improvement. The progress showed in Slide 15 (Progress—Validation of Powertrain Technologies) is confusing by inserting the simulated benefits into the middle of actual validated testing results, which still cannot help the reviewer understand the progress made so far. This becomes a trend of Volvo's presentation style, which is not helpful.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The work across the project team looks really good, with leveraging of abilities at many partners to achieve gains across the full vehicle and powertrain spectrum.

Reviewer 2:
The reviewer noted that work by project partners is indicated throughout the presentation.

Reviewer 3:
The project team includes a cross section of expertise as desired in the FOA. Input from the fleet member was not significantly discussed in the presentation; it is relevant to key FOA goals to establish commercial viability, such as operational cost impacts, impacts to service centers, training, warranty, reliability, resale, etc. The use of SwRI for engine testing and research for the program was a good choice for independent and objective project input. The use of ORNL in evaluating higher pressure impacts with respect to catalyst samples was an excellent choice to bring in expertise for this significant program risk area.

Reviewer 4:
There is a comprehensive list of collaboration companies and mentions of how they helped in various system and component development during the review. The reviewer appreciated having two fleets, from different market segments on the team. More evidence of their engagement would be appreciated.

Reviewer 5:
The reviewer affirmed a nice addition bringing in NACFE. It was clear where University of Michigan and ORNL contributed, but for all the suppliers listed as collaborators, it was unclear whether they were contributing research or just supplying parts.

Reviewer 6:
Although there were shared logos and a team photo at Metalsa, the presentation lacked much detail on the interactions with partners and the collaboration and coordination of the wider team. If the overall team is meeting results, it gets the benefit of the doubt that the teamwork is functioning well enough for this project.

Reviewer 7:
The team member slide should be put back into the main presentation rather than Reviewer-Only slides. Also, it would be helpful if a company logo can be added to the slides, where its contribution is made, which can help the reviewer and the reader understand how the team helped the program.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer looked forward to the completion next year.

Reviewer 2:
The proposed work plan looks good and addresses the outstanding technical items. The reviewer would have liked to see some more discussion of the 55% BTE path and what can be done to deal with possible setbacks there.

Reviewer 3:
Future work is limited for the timing of this project. The team is committed to staying on course during COVID-19 challenges. The reviewer affirmed well done.

Reviewer 4:
The reviewer asserted that only a small mention is provided for the future work.

Reviewer 5:
Given how far through the program this team has ventured, it does not appear that significant future research is needed as much as completing the prototype and conducting the validation testing. It will be interesting to see

if a waste heat recovery system with loops for both coolant and exhaust recovery is a viable option to take forward to fleets for production. Adding too much complexity to diesel engines will drive fleets to battery electric and hydrogen fuel cells to avoid systems that they feel are too complex and challenging to support with their stressed-out equipment maintenance and support systems.

Reviewer 6:
Future work with respect to the program schedule is presented logically with the majority of the key project decision point now accomplished. Future work was described as optimizing the 48 V mild-hybrid and energy management system based on initial results and developing and integrating the 55% BTE engine in the demonstrator. There was, however, no mention of detailed commercialization opportunities, realities, and plans, a goal from the FOA. Comparison of the potential from the demonstrator should also be put in context of MY 2021 production vehicles, not just the 2009 baseline, especially as it relates to commercialization potential. Fleet feedback on operational potential and ramifications of the technologies, such as warranty; reliability; service center configuration; service technology and driver training; compliance with pending EPA, Air Resources Board, and other emissions standards;, etc., should be included.

Reviewer 7:
The reviewer commented that just three sentences on the proposed future research on Slide 16 of the project summary is too simplified. More detailed steps on research and future development would be helpful.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is highly relevant to DOE goals for improving efficiency.

Reviewer 2:
The project directly supports the DOE VTO program goals.

Reviewer 3:
Class 8 HD is by far the largest contributor to national GHG emissions, and it is critical that we have ongoing research in this area.

Reviewer 4:
The reviewer commented yes, the project has high value to truck fleets that are seeking a lightweight 4x2 configuration and will probably light up the eyes of some within the industry. It certainly does not fit all applications within trucking, but that is acceptable as many fleets order specifically what they desire, given their duty cycles, applications, and customer needs.

Reviewer 5:
It appeared to the reviewer that the work is relevant. Some indication on cost-benefit should have been given.

Reviewer 6:
This project supports the overall DOE objectives because of 55% BTE on the engine and a stretch goal of 120% improvement on the vehicle.

Reviewer 7:
The project relevance focuses on key technologies, such as electrification of accessories through the use of 48 V systems, incorporation of waste heat recovery technologies, lightweighting, improved aerodynamics, improved tire rolling resistance, improved lubricants and coatings, improved driver assistance systems, etc. What appears to be missing seemed to be significant discussion of the commercial viability of these choices and any discussion of applicability to expanding market volumes and future proofing tractor technologies, such as applicability of the 48 V accessory systems to battery electric, fuel cell electric, and other alternative fuel vehicles also in the works with the Volvo Lights project, its subsidiaries, and partners.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that budget and spend rate both look good for the project.

Reviewer 2:
Resources appeared adequate to the reviewer.

Reviewer 3:
The reviewer noted that the project is pretty much on schedule with the current resources.

Reviewer 4:
The reviewer remarked resources seem sufficient.

Reviewer 5:
The team appears well positioned to complete the build and testing.

Reviewer 6:
The reviewer commented that they should have all they need to complete the program.

Reviewer 7:
The 2017 and 2018 AMR reviews showed a program budget of $40 million. The 2019 AMR review grew this number to $50 million, maintaining the original $20 million DOE share. The 2020 AMR review maintains the $50 million number, with no explicit issues described with respect to COVID-19 procurement and manpower challenges. Any extension of program timelines due to COVID-19 related issues at OEM or Tier 1, 2, or 3 suppliers, may include additional, previously unplanned budget impacts for manpower and expediting costs for procurements. Insufficient information was provided in the review to determine extent of remaining project funding.

Presentation Number: ace102
Presentation Title: Cummins-Peterbilt SuperTruck 2
Principal Investigator: Jon Dickson (Cummins-Peterbilt)

Presenter

Jon Dickson, Cummins, Inc.; Ken Damon, Peterbilt Motors Company

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 71% of reviewers indicated that the resources were sufficient, 29% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

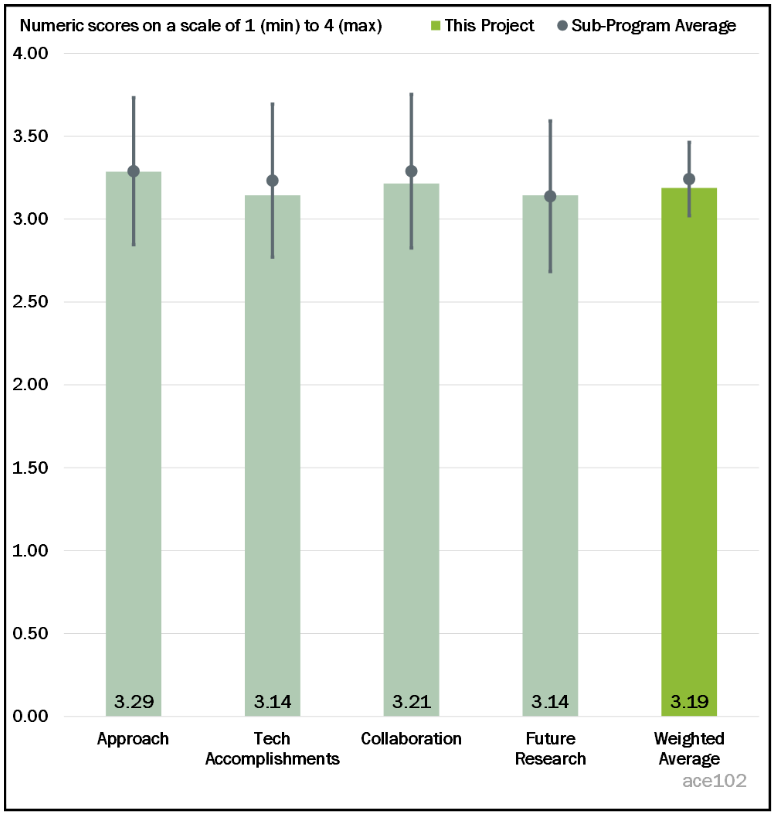

Figure 1-11 - Presentation Number: ace102 Presentation Title: Cummins-Peterbilt SuperTruck 2 Principal Investigator: Jon Dickson (Cummins-Peterbilt)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project continues to exceed expectations with a path to put the 55% BTE engine into the demonstration truck, which is well beyond what was envisioned in the proposal call. The rest of the project is equally far looking, with extensive development to build a truck that looks like it will achieve far more than what was required.

Reviewer 2:

This team continues to show its superior approach to the high efficiency demonstrations of SuperTruck, with an “all of the above” approach that is nicely illustrated on Slide 8.

Reviewer 3:

The project was very well designed, and the approach is technically sound. Use of the new engine platform by combining all the experience and technologies developed under the previous SuperTruck program allows the project a high chance of meeting the program goal.

Reviewer 4:

There were numerous examples of technologies that may carry over well into production. The bladder-controlled cab extenders are quite logical to the challenges of ever-changing wind directions. The combination of aluminum and steel for the frame rails brings the best of both worlds into a system that does not add complexity to the fleet in operations or maintenance. The functionalities of both 6x2 and 6x4 configurations are a beautiful marriage of operational needs. Overall, the project brings many great ideas forward for better industry understanding.

Reviewer 5:
The project team's technical approach is competent. Technical barriers to meeting or exceeding FOA goals have been identified and addressed up to the spring of 2020 when the challenges from COVID-19 impacted hardware delivery and manpower. The progress on achieving 55% BTE engine has been on track with expected one-for-one schedule slip from COVID-19 work stoppages; however final integration into a complete vehicle is required to highlight any software and hardware integration issues. Aerodynamic development and analysis have been significant but need validation on the real vehicle in actual real-world conditions. Progress on the 48 V mild hybridization has been significant and positive. The team did not discuss trailer partner involvement and technical progress there. Progress made on tire Crr reduction was significant, but details were lacking in the presentation. Discussion of progress toward commercialization and applicability to future vehicles was minimal in the presentation. The lightweight chassis is innovative, combining a range of new technologies, and represents significant progress for the team. Fleet involvement in reducing risk or improving commercialization was not discussed in any detail.

Reviewer 6:
The Cummins-Peterbilt presentation technical approach is divided into engine, powertrain, and freight efficiency demonstrator (Slide 8). Subsequent slides go back and forth in and out of these groups, making it difficult to assess the technologies presented (Slide 9). The BTE gains shown should be tied into a descriptive summary to allow the reviewer to provide an adequate evaluation of the merits and feasibility of the claims. Brief and inadequate descriptions are provided for heat transfer and the heat recovery turbine. For example, no material specification is provided for the new designs; turbine outlet pressure ranges given are not discussed with respect to the system and cycle pressure ratios capability. Similarly, on the vehicle side, details should be provided to describe the drag, weight, and rolling benchmarks provided.

Reviewer 7:
It appears to the reviewer that the slides are poorly arranged. The approach and technical slides are frequently interchanged.

Reviewer 8:
The reviewer was disappointed with this review as there was very little detail for an appropriate evaluation, particularly on vehicle side.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The technical accomplishment on the engine side with 53.5% BTE demonstration on the test bench is impressive. The project also made striking progress on vehicle related technologies, including aerodynamic drag with 63% reduction achieved, substantial weight reduction with 4,700 lb achieved, and rolling resistance reduction with 33% achieved. It seems that all of technical achievements demonstrated so far point to a clear path to achieve both engine and vehicle program goals.

Reviewer 2:
The project demonstrated significant progress toward exceeding FOA goals projected at 170% improvement in freight efficiency, including exceeding program targets for aerodynamic drag reduction, weight reduction, and rolling resistance improvement. Progress at a vehicle system level has been evaluated for a variety of technology implementations evaluated through analysis, bench testing, creation of functioning electrical mock-ups, and build and testing of a complete on-road mule tractor. Lightweighting of the chassis is a significant accomplishment with a hybrid dual material approach and integration of functions such as the chassis frame member acting also as an air tank. The incorporation of active ride-height control on both tractor and trailer permits significant aerodynamic drag reduction in a near-term feasible commercial product. The progress on WHR system components has been measurable through analysis and bench testing. Development of the new, dual entry turbine progressed to functioning hardware packaged at the engine level. The attention to

demonstrator vehicle, on-road safety through durability, floor stiffness, global static stiffness, jack knife impact, and roof crush-rollover analysis is a significant project positive, as well as a contributor to evaluating commercial viability.

Reviewer 3:
The presentation contained more than adequate technical results and implementation information that were lacking from some of the other teams.

Reviewer 4:
The efficiency demonstrated to date on the engine is outstanding and already best-in-class. The truck engineering looks to be equally well developed; the reviewer particularly appreciated the call-out on safety. The reviewer had no doubt that all the teams are taking that seriously, but putting in a slide discussing the efforts in that direction is a good addition to merely talking about the efficiency gains.

Reviewer 5:
The slides are poorly arranged; Approach and Technical slides are frequently interchanged. Work around the chassis, specifically the air suspension and disconnect axles, is meritorious. The team, however, fail to provide meaningful technical information. Aspects that should be discussed are stability, response times, and power requirements, and impact on the freight efficiency. Notices as to cost and customer response should also be brought up.

Reviewer 6:
Completion of the mule vehicle demo is a significant accomplishment for this team. It is also good to see that the 55% demonstration engine will be used in the final demonstration vehicle too. The one area that was not clear was the intent to retain heat in the piston via material selection and component design. This was listed under “Key Technology Development” on Slide 11. Is this not the opposite of the temperature-swing thermal coatings being done by the other teams?

Reviewer 7:
The reviewer suspected that technical accomplishments and progress are in line to meet the overall goals of this project, but there was not enough evidence in the slides or presentation to ascertain. There was no waterfall chart that describes details of where the efficiency is being attained.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer stated that the work by the project partners is indicated throughout the presentation.

Reviewer 2:
The project seems to utilize all partners, significantly strengthening the chance to meet the program goals.

Reviewer 3:
The use of team company logos throughout the presentation made it easy to see that there are a lot of participating suppliers and industry leaders supporting this project. If the results of the integration of so many ideas are as well done as this slide deck, the performance of the vehicle should be impressive. Hopefully, this is a true representation of the project and not just excellent PowerPoint engineering.

Reviewer 4:
The collaboration appears strong. It is difficult to tell how much of the work is a true collaboration and how much is a supplier-customer interaction. There is ample evidence of strong technical development across the entire project though, so the reviewer is giving the benefit of the doubt to the team.

Reviewer 5:
The system level approach of this team is evident as the only non-vertically integrated engine and vehicle OEM SuperTruck team. The project team members include all the functional members requested in the FOA. Greater discussion of active participation and contribution to progress by the fleet, trailer, and tire members is needed. Collaboration to date has been excellent, until COVID-19 impacted schedules in March 2020. The ramification of the vehicle OEM halting vehicle integration work for the remainder of 2020 means an effective 8-month gap in vehicle integration efforts and a 1-year slip in the testing schedule. This gap increases risk that the engine manufacturer and the vehicle manufacturer may not be in sync, that experience on the project teams may change from personnel reassignments or departures, that funding demands in 2021 may increase to expedite procurements and obtain facility and technical support, that troubleshooting time and complexity for the vehicle in 2021 may increase, etc. Budget limitations may further reprioritize program activities. These challenges may lead to the project not meeting critical performance objectives. Alternatives for continuing collaboration and providing necessary resources should be investigated by the team. The trailer team member was not identified in the slides but was discussed in the verbal part of the presentation.

Reviewer 6:
The reviewer commented that there is a single slide showing collaboration, but not enough evidence or discussion on how these suppliers delivered their products with "collaboration" rather than a simple supplier-customer relationship. These projects should help teach others (160 people in the audience) about how collaborations can help deliver against such significant challenges.

Reviewer 7:
The reviewer asked if the suppliers shown on Slides 19-22 are developing new technologies, or just supplying previously developed technology. Is any of that technology in the marketplace?

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
There is a strong plan in place to achieve and exceed the SuperTruck 2 goals, and the work progress suggests no significant problems with meeting the targets.

Reviewer 2:
The reviewer affirmed the project looks good. The reviewer looked forward to the final year's demonstration progress in next year's presentation.

Reviewer 3:
The proposed future research covers all of the necessary steps to ensure that the program is on the way to achieve the program goals.

Reviewer 4:
Much of the research is now just needing to be modeled in the test vehicle and validated and optimized on the track and on the road. If the team's confidence proves out, this should be a great combination of ideas and integration from many different parties.

Reviewer 5:
Future research is pretty limited to procuring parts and completing the build for tests. The reviewer understood the decision to break up the team given the recession situation.

Reviewer 6:
The reviewer asserted that the schedules shown are too brief and vague. Entries such as 'Vehicle Design Development' should be proven down to provide a more comprehensive work overview. Statements such as 'simulate in-use truck environment' should be accompanied by a description of what this entails.

Reviewer 7:
Proposed future work is impacted by team member reprioritization of funding and personnel. The ramification of halting OEM vehicle integration work for the remainder of 2020 means an effective 8-month gap in vehicle integration efforts and a 1-year slip in testing schedule, increasing the risk that the engine manufacturer and the vehicle manufacturer may not be in sync, that experience on the project teams may change from personnel reassignments or departures, that funding demands in 2021 may increase to expedite procurements and obtain facility and technical support, that troubleshooting time and complexity for the vehicle in 2021 may increase, etc. These challenges may lead to the project not meeting critical performance objectives.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project directly supports the DOE VTO goals of developing high efficiency technology for freight movement in the United States.

Reviewer 2:
Reduced heavy duty fuel consumption is directly in line with DOE objectives.

Reviewer 3:
Class 8 HD tractors are by far the single biggest contributor to GHG emissions, and the DOE should maintain a constant stream of projects to assist in efficiency efforts.

Reviewer 4:
This project very well supports the overall DOE objectives because of 55% BTE and a minimum 125% FTE improvements that are likely to be achieved.

Reviewer 5:
The reviewer commented that the work is relevant. Some indication on cost-benefit should have been given.

Reviewer 6:
Many of the ideas that make up this concept vehicle can be applied to production tractor-trailers. It would be great to see how the wider industry will accept the concepts as part of their specifications and operations. The ideas could optimize future vehicles without being so complex that fleets refuse to adopt them into their specifications.

Reviewer 7:
Project relevance focuses on key technologies, such as electrification of accessories through the use of 48 V systems, incorporation of waste heat recovery technologies, lightweighting, improved aerodynamics, improved tire rolling resistance, improved lubricants and coatings, improved driver assistance systems, etc. What appears to be missing seemed to be significant discussion of the commercial viability of these choices and any discussion of applicability to expanding market volumes and future proofing tractor technologies such as applicability of the 48 V accessory systems to battery electric, fuel cell electric, and other alternative fuel vehicles also in work with both Cummins and Peterbilt, their subsidiaries, and partners.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project team has all it needs to achieve the program goal in a timely manner.

Reviewer 2:
The reviewer stated that the spend rate and budget look good for the work plan.

Reviewer 3:
The reviewer commented that resources appear adequate.

Reviewer 4:
There is no indication that lack of funds will prevent the final demonstration vehicle from being built and meeting the project goals.

Reviewer 5:
Although the reviewer rated the project team as sufficient, the reviewer had significant doubts given the stated delays in the project. If financial obstacles remain, given a slow recovery out of the current challenges of both COVID-19 and a financial recession, this project may be losing momentum and expertise required to produce the results promised. It would be a shame to have gone so far and yet let the trip slip away without concluding a successful journey. Please watch this one closely and bring home the delivery to the dock as promised.

Reviewer 6:
The reviewer understood disbanding the team, but did not see a plan to document and even close out aspects of the project such that it can be restarted to complete the project efficiently. The reviewer was concerned about meeting program deliverables once the project restarts.

Reviewer 7:
The project reported spend to date at $35.8 million against net budget allocation of $40 million. Reporting net program spend to date is important to ascertain remaining funding against discussed plans. The project also detailed a COVID-19 schedule and manpower impacts at the vehicle OEM introducing a 1-year delay in the project, and the engine manufacturer described a 3-month impact for 55% BTE confirmation. The project did not identify a need for additional funding, rather accepted schedule slips. However, realistically there may be additional manpower and procurement costs such as storage, refurbishment, expediting, and possibly contract labor to fill short-term project needs once the vehicle OEM restarts work in 2021 from a more than 8-month hiatus. Maintaining the original scoped efforts may be at risk without additional funding. Details of a recovery plan with respect to budget and deliverables should be provided.

Presentation Number: ace103
Presentation Title: Development and Demonstration of a Fuel-Efficient Class 8 Tractor and Trailer SuperTruck
Principal Investigator: Russell Zukouski (Navistar)

Presenter

Russell Zukouski, Navistar

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 33% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

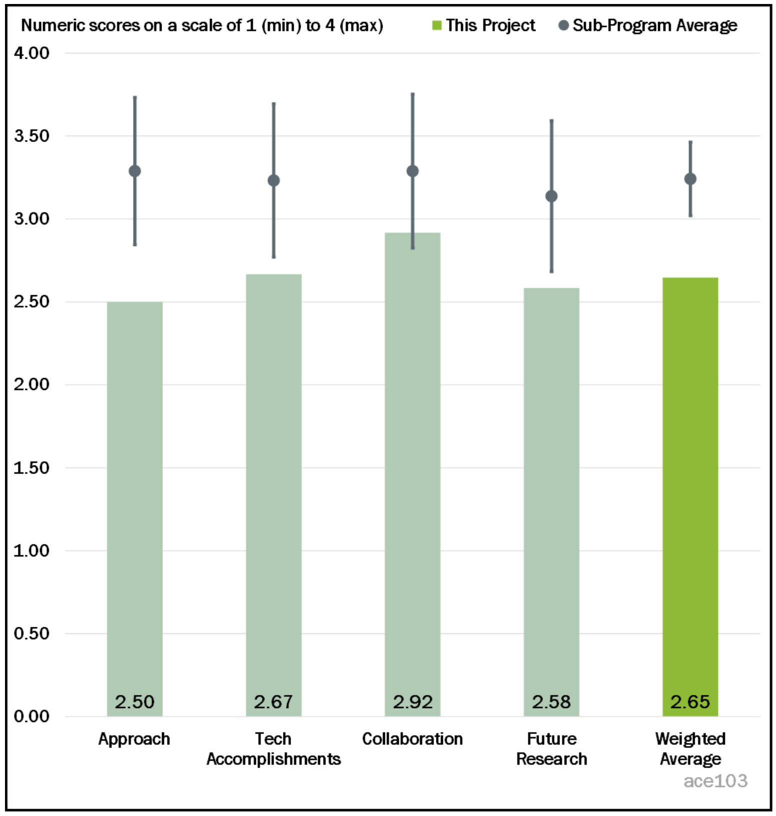

Figure 1-12 - Presentation Number: ace103 Presentation Title: Development and Demonstration of a Fuel-Efficient Class 8 Tractor and Trailer SuperTruck Principal Investigator: Russell Zukouski (Navistar)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project is well along toward completion and the overall approach remains solid. The integration of a higher voltage hybrid system is positive for future applications where 14 V systems have limitations on electric-only operation.

Reviewer 2:

The project demonstrated approaches to attaining or exceeding FOA program goals. However, there are a significant number of system design selections or optimizations still in process at the engine level late in the project. The extensive use of carbon fiber for cab structure and trailer was described by the presenter as far from commercial viability due to the raw cost of carbon fiber for the foreseeable future. As commercialization potential within a few years is a key element of the FOA goals, the choice of this material solution is both a project commercial risk and added complexity, cost, and schedule to the project, and perhaps the effort should have focused on nearer term alternatives. Evaluation of a gasoline compression ignition (GCI) hybrid architecture is innovative. Fleet feedback on the potential ramifications to operations, maintenance, technician training, industry fueling infrastructure, etc., should have been included in the progress discussions as part of the decision making and eventual commercialization potential. Weight reduction and optimization of the chassis systems along with high-strength steel (HSS) steel showed progress, and evaluation of multiple shapes was performed to allow confidence in selection.

Reviewer 3:
The approach seems on track to meet project deliverables, but this review was very difficult to follow. Part of the reason is due to three presenters and it seemed very similar to prior years. The reviewer was concerned with delivery in the final year given a number of open issues.

Reviewer 4:
The presentation team seemed to have spent a lot of time talking about ideas and areas that were not proving out well for the project. Some areas are great while others, like the exhaust aftertreatment system and heat damage to the composite frame structure, are obviously challenging the team.

Reviewer 5:
The approach with continuation of the gasoline engine in the project is highly questionable. Although the gasoline engine can offer some benefits to the light loads, there would be virtually no chance that this gasoline engine would be installed into a demonstration vehicle to meet the program goal. In addition, this gasoline engine has no chance to meet 55% BTE goal as well. Then why would the project continue funding this technology? A clear justification would be required.

Reviewer 6:
Little consideration was given to the approach. The project team appeared to go right into the technical accomplishment section.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
It was great to see that operations can include a 20-30-mile range of no internal combustion engine (ICE) combustion while on hybrid electric mode.

Reviewer 2:
The team is pursuing many approaches to achieve a difficult target of 55% peak efficiency but appears to be making progress. It is difficult to fully assess without disclosure of more data.

Reviewer 3:
There has been good progress made on the vehicle side on aerodynamics, weight reduction, cooling, and powertrain. However, 50.4% BTE at this stage is behind to its competitors. Although nice graphics have been generated to show the progress on combustion, fuel system, and air management, it is not clear how this progress can be attributed to overall BTE improvements in an incremental manner.

Reviewer 4:
There are a significant number of system design selections or optimizations that appear to be still in process at the engine level well into budget period 4. The extensive use of carbon fiber for cab structure and trailer was described by the OEM presenter as far from commercial viability due to the raw cost of carbon fiber for the foreseeable future. As commercialization potential within a few years is a key element of the FOA goals, the choice of this material solution is both a project commercial risk and added complexity, cost, and schedule to the project, and perhaps the effort should have focused on nearer term, more commercially viable alternatives. Evaluation of a GCI hybrid architecture is innovative, and progress was shown on development and testing. Fleet feedback on the potential ramifications to operations, maintenance, technician training, infrastructure, etc. should have been included in the progress discussions as part of the decision making and eventual commercialization potential. Weight reduction and optimization of the chassis systems along with HSS steel showed progress, and evaluation of multiple shapes was performed to allow confidence in selection. A traditional schedule waterfall chart was shown in 2019 AMR but was missing from 2020 AMR presentation, making assessment of progress more challenging for reviewers.

Reviewer 5:
Good progress on key decisions to move to final integration and build. The reviewer was disappointed in the lack of detail in the slides and presentation around the objectives of efficiency and in particular commercialization. The team almost ignored the requirement of assessing fleet interest in adoption. The reviewer doubted the fleet identified is too involved.

Reviewer 6:
Cylinder activation work results applied to representative city drive are an impressive 2.9% fuel consumption gain. But, this vehicle application is likely to be longer haul. Overall, it would be advisable that Navistar applies the FE criteria for all their technology portfolio on the same cycle. This is important for assessing the overall FE impact

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration across the project team seems to be good. The contribution by each key team member has been appropriately acknowledged.

Reviewer 2:
It appears to the reviewer that work by project partners is indicated throughout the presentation.

Reviewer 3:
Collaboration on the vehicle structure appears very constructive and is making good progress. Engine features such as air handling appear well coordinated with major suppliers.

Reviewer 4:
Collaboration was noted with respect to a few of the suppliers, but very little evidence was described for National Laboratories and end-user fleet. The reviewer wondered if there is some way that an advisory committee could be incorporated into these projects.

Reviewer 5:
The project team includes a cross section of expertise as desired in the FOA with the exception of a tire manufacturer. Input from the trailer or fleet team members was not significantly discussed in the presentation, which is relevant to key FOA goals to establish commercial viability such as operational cost impacts, impacts to service centers, fueling infrastructure, technician and driver training, warranty, reliability, resale, etc. The trailer team member was not identified in the slides, only the composites manufacturer. Co-development of predictive cruise control and ACC controls were attributed to University of Michigan. Is this the same group that is working on the Daimler SuperTruck 2 (ST2) PCC and ACC systems? If so, they were not identified in the slides.

Reviewer 6:
The presentation team seemed nervous and struggling to present to our reviewers. The reviewer was not sure how that reflects on the project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The team seems committed with resources to finish even given COVID-19 challenges.

Reviewer 2:
It sounds like tough decisions have been made on which technologies to drop and which to carry forward. Optimizing hybrid operations with predictive cruise control could yield some interesting results for future production hybrid vehicles.

Reviewer 3:
The project is nearing completion with the engine target not quite achieved, but the future path looks reasonable. The future research steps were defined well in some subtasks, but not addressed very completely in the vehicle area.

Reviewer 4:
The proposed future research is not clear, specifically on the vehicle site, although the next steps on the engine side have been mentioned throughout individual progress slide. A dedicated slide for the future work would be useful to help the reviewer to understand the project's future direction.

Reviewer 5:
The absence of a traditional schedule waterfall chart previously shown in the 2019 AMR review but omitted from the 2020 AMR review presentation made the assessment of future research work challenging. A significant number of engine-related decisions appeared to be still in flux well into 2020 Budget Period 4, the period focused on tractor-trailer fabrication, integration, commissioning, and demonstration. The relationship of development work and testing with the mule vehicle with respect to applicability to the hardware and software for the demonstration vehicle was not discussed; perhaps the migration of systems from the mule to the demonstrator is expected, but no declaration of migration was shown in the presentation. There are significant software and hardware integrations ahead for this team, and adequate time and resources for troubleshooting software issues are not clearly identified as a risk factor to cost, schedule, and testing.

Reviewer 6:
There appears to be a rather large gap between the engine demonstration status and target improvements (Slide 4). This year's work is indicated as a "down-selection" period, ahead of the commission and demonstration. How does Navistar expect to bridge this gap? The vehicle freight efficiency improvement roadmap (Slide 11) lacks clarification if these are projections, simulation estimates, or actual data. Little confidence is provided on the following slides of its capability to meet the stretch goal target. The continued efforts of Slide 17 are vague. Statements such as "WHR system development" should be given much greater thought and conveyed here, specifically with respect to the gaps noted in their roadmap to attain the program goals.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Class 8 HD tractors GHG reductions are key to DOE goals as they are by far the largest fuel user. The DOE should maintain a constant stream of projects in this area.

Reviewer 2:
This project supports the overall DOE objectives if it can achieve 55% BTE on the engine and 140% improvement on the vehicle.

Reviewer 3:
Hybrid configurations seem highly likely (might be diesel but it also might be hydrogen), and the work being done here to operate in an engine-off mode when possible is a step in the right direction.

Reviewer 4:
The project is discovering and demonstrating technology for reducing fuel consumption and emissions from medium- and heavy-duty vehicles (MHDVs) in the freight sector.

Reviewer 5:
The project relevance to potential future production solutions to reduce emissions and improve efficiency is significant. However, the technology choices per the FOA need to address commercial viability in a short time frame of 2-3 years. The choice of carbon fiber as a major structural component for the cab and trailer are worthy of research, but as R&D activities rather than core choices for the SuperTruck II effort. The chicken-and-egg aspect of carbon fiber is that raw material price is high with only marginal decreases over time due to low volumes; the reviewer recognized that for volume to increase so that price may decrease, projects need to implement carbon fiber in production uses. Projections for market adoption modeling of carbon fiber would be beneficial to this team making the case with the assistance of ORNL researchers with expertise in the material.

Reviewer 6:
The reviewer remarked that the overall work is relevant. Some indication on cost-benefit should have been given.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer affirmed the resources appear adequate.

Reviewer 2:
The project is well along and does not seem to have hit any major setbacks, which would stretch the resources.

Reviewer 3:
The project reported no significant detail on budget spend to date nor the impacts of COVID-19 related manpower and procurement issues. The project is reporting completion to the original end of 2021 schedule. The 2020 AMR report states 67% complete. Impacts to the OEM and Tier 1, 2, and 3 supply bases from COVID-19 shutdowns reasonably should be expected, so to stay on schedule with original work content would require expediting, overtime, and other schedule recovery methods that may pressure the budget. The project should provide a level of detail to permit assessment of project resources against scoped work content and schedule. Prior year AMR reports for 2017, 2018, and 2019 AMRs similarly do not report spend to date details or remaining budgets.

Reviewer 4:
Responding to the question of how sufficient resources are for the project, this reviewer indicated that there is little evidence, otherwise.

Reviewer 5:
If resources are moved from areas that have been eliminated to areas of future focus, the team should be on track.

Reviewer 6:
The reviewer was not sure if the project will have sufficient resources to achieve the engine program goal.

Presentation Number: ace118
Presentation Title: CLEERS Passive NOx Adsorber (PNA)
Principal Investigator: Janos Szanyi (Pacific Northwest National Laboratory)

Presenter

Janos Szanyi, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

Three reviewers indicated that the project was relevant to current DOE objectives while the other reviewer indicated that the project was not relevant. All reviewers indicated that the resources were sufficient.

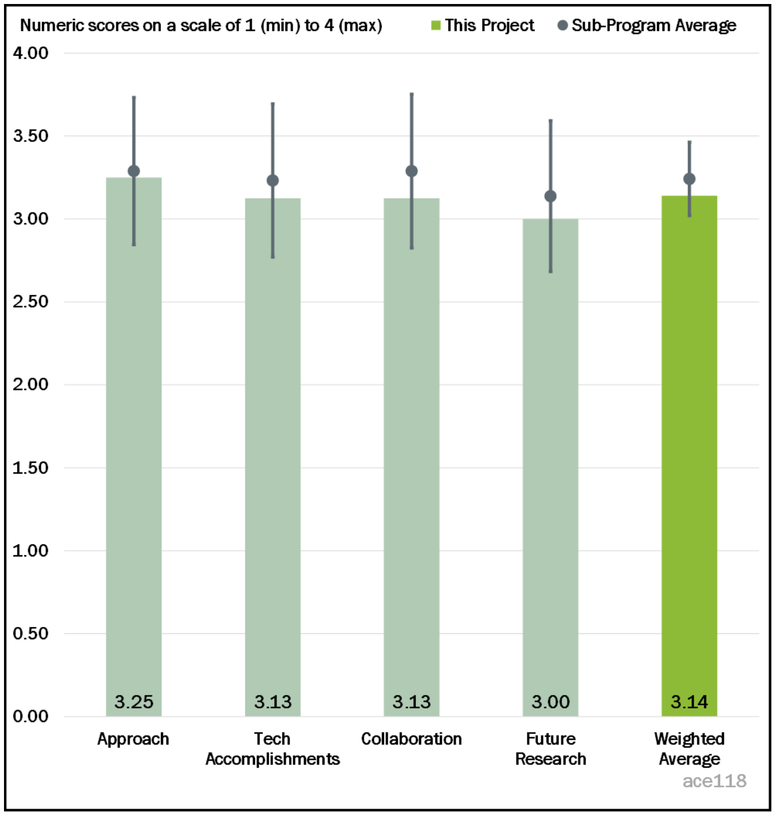

Figure 1-13 - Presentation Number: ace118 Presentation Title: CLEERS Passive NOx Adsorber (PNA) Principal Investigator: Janos Szanyi (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project has met, and is on track to meet, its annual milestones that include key technical barriers of NO_x adsorption capacity, reasonable NO_x release characteristics, improved zeolite thermal stability, and understanding important hydrothermal durability mechanisms.

Reviewer 2:

This is a solid and well-planned exploration of the fundamentals of NO_x adsorption on Pd exchanged zeolites, building off of previous work. The work trends closer to basic research than applied, but this is somewhat expected. The reviewer asserted that it would be nice to see how this work contributes to modeling, as this is one of the identified barriers.

Reviewer 3:

The project has responded to reviewer comments from last year and put adequate emphasis on cycling and high-temperature stability studies.

Reviewer 4:

The technical barriers for commercial use of the PNA technology are low storage capacity per unit cost of the material; and storage capacity decrease with the use (sulfur, hydrothermal aging, and presence of reducing components) apart from how to effectively use the component in a real-world system. There has been emphasis on selecting the Pd/zeolite by varying the zeolite in this work, but not much has been done to keep the storage level high with different aging. Also, raw data curves are shown in the presentation without much processing of the data to bring new features from these experiments, e.g., storage capacity with respect to temperature, efficiency of storage when some NO_x is already stored, etc.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project has identified a promising zeolite-based PNA with good hydrothermal stability and has developed an understanding of the impacts of CO concentration on NO_x desorption for this PNA material.

Reviewer 2:
Good progress has been made against the milestones, and the issues raised by prior work (such as high-temperature deactivation) are being addressed here.

Reviewer 3:
This project has generated abundant data that have fair connections to real-world applications, despite the delays caused by the global pandemic.

Reviewer 4:
In this work, cause of degradation of PNA material such as HTA and effect of CO/ HC are illustrated. The goal of the project was to provide molecular level understanding, but it was not clear where Pd is in the zeolite, how many types of Pd there are, and what makes Pd special that it stores NO while Pt cannot. There are some conflicting results from the literature about the impact of low concentration of CO on NO_x storage and release. For the most part, the work seems like a report on making a few varieties of PNA by changing the zeolites, but it is not much focused toward understanding the cause and providing solutions for improvement.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer stated that promising new materials have been compared and analyzed.

Reviewer 2:
The contribution of key teams is mentioned in the presentation.

Reviewer 3:
Collaboration appears to take place primarily through monthly teleconferences and sample exchanges with other laboratories. It is good to see collaboration across National Laboratories (ORNL), industry (BASF), and academia (Sofia University).

Reviewer 4:
The project would benefit from more collaboration with ORNL staff who are also working on PNAs. The topic of HC interactions on the PNA, in particular, looks like it needs to be addressed under more realistic exhaust gas conditions that are being used in another ORNL PNA project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
As this project is completed later this year, work is rightly targeting measuring performance metrics using more realistic exhaust gas conditions.

Reviewer 2:
The future work is well planned, but it would be good to see more emphasis on application.

Reviewer 3:
Some of the proposed work should have been completed during the course of program.

Reviewer 4:
The team promised a large amount of work. For VTO projects, the deliverable should focus on creating better solutions. The compatibility with a diesel oxidation catalyst (DOC) would be particularly intriguing.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
PNA is critical for diesel emissions control.

Reviewer 2:
The reviewer commented that work on PNAs are an important enabler of cold-start NO_x performance.

Reviewer 3:
This work directly addresses several objectives put forth in the U.S. DRIVE ACEC Roadmap with a focus on NO_x abatement for low-temperature combustion.

Reviewer 4:
This project is not very relevant for various reasons, at least for heavy-duty diesel:

- The cost of Pd (active metal for PNA) increased a lot in last few years compared to Pt.
- NO_x storage is not stable and shows some irreversible degradation.
- It is difficult to control in real operation in the presence of NO_x from the engine.

However, this project is somewhat relevant for light-duty diesel. The scope of PNA in those applications is also limited.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
According to the reviewer, resources are sufficient for this project.

Reviewer 2:
Current funding levels appear to be sufficient.

Reviewer 3:
The reaction testing capabilities, characterization tools, and funding level are all appropriate for the proposed research.

Reviewer 4:
The reviewer suggested focusing resources on measuring PNA performance using more realistic exhaust gas conditions.

Presentation Number: ace119
Presentation Title: Development and Optimization of a Multi-Functional SCR-DPF (Diesel Particulate Filter) Aftertreatment System for Heavy-Duty NOx and Soot Emission Reduction
Principal Investigator: Ken Rappe (Pacific Northwest National Laboratory)

Presenter

Ken Rappe, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

All reviewers indicated that the project was relevant to current DOE objectives. Two reviewers indicated that the resources were sufficient while the third reviewer indicated that the resources were excessive.

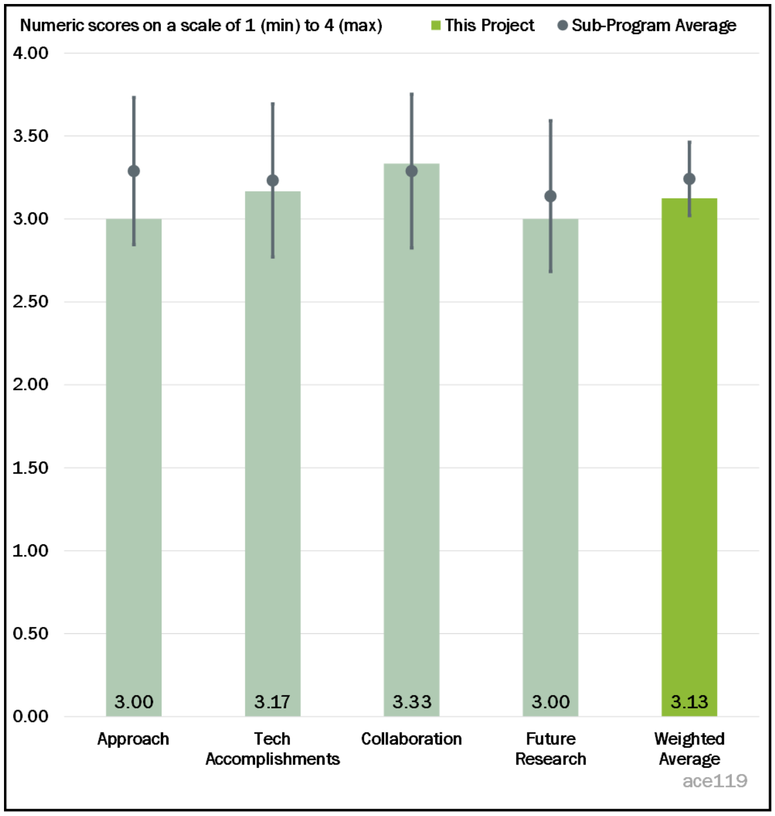

Figure 1-14 - Presentation Number: ace119 Presentation Title: Development and Optimization of a Multi-Functional SCR-DPF (Diesel Particulate Filter) Aftertreatment System for Heavy-Duty NOx and Soot Emission Reduction Principal Investigator: Ken Rappe

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project has uncovered an interesting pathway to improving the passive soot oxidation performance of an SCR coated diesel particulate filter (DPF) using a manganese (Mn)-based additive that increases internal oxidation of nitric oxide NO to NO_2. The performance and durability of this approach under diesel engine exhaust conditions remain to be demonstrated.

Reviewer 2:

The barriers identified are cost effectiveness and durability of aftertreatment devices. While combining units (and reducing system complexity) points in the direction of cost reduction, these barriers are not addressed quantitatively (i.e., the impact on system cost and durability are not addressed directly).

The addition of a selective catalytic oxidation (SCO) phase to the SCRF is an interesting approach to increasing passive soot oxidation. It is good to see the experimental work accompanied by modeling, as the two have potential to inform the other. The reviewer was interested to see the results of the sulfur-poisoning work, as this has weight in the practical applicability of the technology.

Reviewer 3:

Overall, the project used catalyst synthesis to improve oxidation capability to generate more in-situ NO_2, tried reactor and engine tests, and used modeling. Therefore, most of the approach was satisfactory, but all of these concepts were used earlier and are available in the literature; a key bottleneck with in-situ NO_2 generation is sensitive with sulfur and nitrous oxide (N_2O) generation. It would be better if key technical barriers for commercialization of this technology—the effect of sulfur, lower temperature regeneration, and hydrothermal stability—were explored; some of those are in the future work, but the reviewer was not sure as the project is ending in June.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Good progress has been made in characterizing the performance of a Mn SCO-SCR coated DPF. A Mn dimer has been identified as the active site for NO selective oxidation. Work on sulfur poisoning is underway, a key to understanding the viability and durability of this approach. Model development is in progress.

Reviewer 2:
The reviewer recommended further data processing of the experiments to derive relevant parameters, such as what fraction of NO_2 is used in SCR versus soot oxidation. This parameter will change axially and with temperature and would be very useful.

Some of the portrayed advantages of NO_2 generation occurs at temperature higher than 300°C, which helps with soot oxidation but hurts on SCR because of slow SCR and therefore demands higher diesel exhaust fluid (DEF) consumption. It is also surprising that NO_2/NO_x in the feed from 0 to 0.3 does not have any impact on the catalyst with 30% SCO.

Reviewer 3:
The model development appears to be running behind somewhat (scheduled for completion in April but still ongoing). This is understandable given the situation with the pandemic. Some interesting technical results are presented, but it is difficult to tell how far along the path to practical application we are.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There is good collaboration with PACCAR and its suppliers on this project.

Reviewer 2:
Both PNNL and PACCAR teams were well coordinated and shared the roles and findings regularly.

Reviewer 3:
Collaboration appears to be well coordinated but is currently limited to the two cooperative research and development agreement (CRADA) participants, PNNL and PACCAR.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed sulfur-tolerance and modeling work is appropriate and necessary. It would be interesting to see system level impacts, such as the interaction between the design of the SCRF and the DOC. For instance, does the addition of the SCO phase to the SCRF allow for any reduction in PGM loading in the DOC?

Reviewer 2:
Sulfur poisoning studies are underway as this project closes out to begin the assessment of the durability of this concept. If this project is renewed or continued, it seems that this SCR-coated DPF design is ready to get out of the laboratory and move to engine studies to flesh out the durability issues.

Reviewer 3:
The reviewer commented that this is month of June so project should be ended.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This work addresses the barrier "Reduce cost, size, and complexity of emission control system with multifunction catalysts that combine multiple components onto one substrate," as stated in the U.S. DRIVE Roadmap.

Reviewer 2:
SCR-coated DPFs for heavy-duty engines are an important enabler for achieving faster SCR catalyst warm-up and reducing cold-start NO_x emissions.

Reviewer 3:
When the project started in 2016, the concept of combining SCR and DPF was one of the potential architectures to meet future challenges with cold-start emissions. But, this architecture has significant challenges, like hydrothermal stability of the SCR layer, soot cleaning, etc., and one of the challenges of preferential NO_2 consumption in SCR compared to soot was explored as part of this study.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources for this project appear to be sufficient.

Reviewer 2:
The project appears to have sufficient resources to close out the remaining objectives around model development and sulfur impacts.

Reviewer 3:
The total of $2.7 million for the amount of work done for this project seems high when key barriers, such as sulfur and hydrothermal aging, were not addressed.

Presentation Number: ace123
Presentation Title: Temperature-Following Thermal Barrier Coatings for High-Efficiency Engines
Principal Investigator: Tobias Schaedler (HRL Laboratories)

Presenter

Peter Andruskiewicz, General Motors

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 25% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

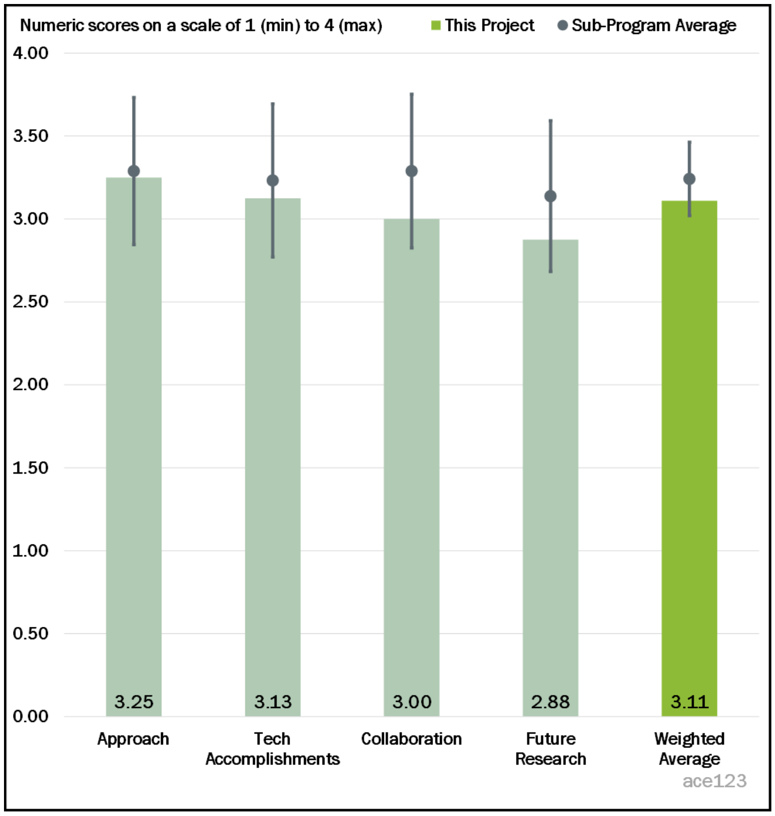

Figure 1-15 - Presentation Number: ace123 Presentation Title: Temperature-Following Thermal Barrier Coatings for High-Efficiency Engines Principal Investigator: Tobias Schaedler (HRL Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The concept of thermal/temperature swing coatings is worth investigating and potentially effective. The difficulty and risk have been borne out in this project. Persistence of investigators is acknowledged. Further work on exhaust components seems like a good idea.

Reviewer 2:

Temperature swing coatings are an area of great interest in the industry now. Novel approaches to achieve these are needed, and this project provides a unique approach that shows very promising results. The ultimate proof will be in the durability, which has always been the downfall of thermal barrier coatings. While the performance of these coatings is very impressive, the development of the seal coat looks like a barrier to commercialization. This project acknowledges that this is still a problem but does not address that issue.

Reviewer 3:

The PI took a practically viable approach to address the project objectives. The project objectives were clearly defined. Going forward, the reviewer requested the inclusion of a percentage target achieved against the program goals to evaluate what percentage of the goal was achieved. For example, there could be an additional bar chart to illustrate the percentage targets achieved clearly on the project objectives slide.

Reviewer 4:

Project appears to have had significant challenges regarding the development of prototype components. The test sequence seems technically sound, but some of the challenges encountered during the process could have been avoided with a better technical plan of execution.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Significant progress is made, and practical viable solutions are being considered and demonstrated.

Reviewer 2:
Although not all the hoped-for targets and durability were achieved, the project has generated important new data about swing coatings. The outcomes for exhaust components should be interesting. New intellectual property (IP) has been developed.

Reviewer 3:
It is not clear for what budget period the accomplishments presented were achieved. If the reviewer assumed that the no-cost time extension period (during which everything was on pause) just ended, then it looks like the project just restarted. The reviewer was giving the benefit of the doubt that the reported results were for a 1 budget year period, and the accomplishments for this period of time with the material application and sealing are very good.

Reviewer 4:
Schedule has been significantly delayed due to challenges with piston coating and machining. Overall fuel economy improvements have been relatively low (2.7%) for the amount of funds this project has expended.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
It appears to the reviewer that there were effective collaborations leading to practical solutions.

Reviewer 2:
The partnering with GM and suppliers has been okay.

Reviewer 3:
The reviewer noted that there was only one partner on the program. It is a major OEM, so it can support testing and guidance on objectives. It probably would have been good to have a partnership with Tier 1 and 2 suppliers that could have helped alleviate some of the technical challenges encountered.

Reviewer 4:
The reviewer questioned why the collaborators' names were not in the presentation. Saying "multiple industry partners" and "Tier 1 supplier" is not much to go on to make an evaluation. The reviewer also found it hard to tell what HRL did and what GM did.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The project is nearly over, so completion of work on exhaust ports and final tests of pistons should be key in the plans. Documenting the entire project is important.

Reviewer 2:
The reviewer commented that the proposed future work plan is satisfactory. Benefits of the coatings have been shown (although the impact is relatively small). The reviewer would have preferred to see some effort focusing on the durability of the surface coatings, considering the challenges that were encountered with the project.

Reviewer 3:
The project is scheduled to end at the end of 2020, so the future work would need to be funded through a different mechanism. It was difficult to tell, but it appears that the final year milestones will be met.

Reviewer 4:
The PI and collaborators need to make it more obvious when and what measure to use to take go/no-go decisions to continue with the project milestones.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Performance benefits of thermal swing coatings and their ability to enable fuel economy improvement as well as provide higher quality heat for exhaust aftertreatment meet the DOE VTO program objectives.

Reviewer 2:
Thermal barrier coatings improve fuel efficiency and support overall DOE objectives.

Reviewer 3:
The project supports improved energy utilization for internal combustion engines.

Reviewer 4:
Thermal swing coatings are indeed a fundamentally sound path to higher engine efficiency, yet difficult to perfect and commercialize.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
In reviewing this project more than once, the financial resources have appeared adequate.

Reviewer 2:
The project PI and collaborators appear to have sufficient resources that are relevant to achieve practical viable solutions.

Reviewer 3:
The reviewer commented that the project is coming to an end.

Reviewer 4:
The reviewer opined that this project was provided significantly too much funding for the relatively small improvements it has achieved.

Presentation Number: ace124
Presentation Title: SuperTruck 2 - PACCAR
Principal Investigator: Maarten Meijer (PACCAR)

Presenter

Maarten Meijer, PACCAR; Ben Grover, Kenworth Truck Company

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers indicated that the resources were sufficient, 17% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

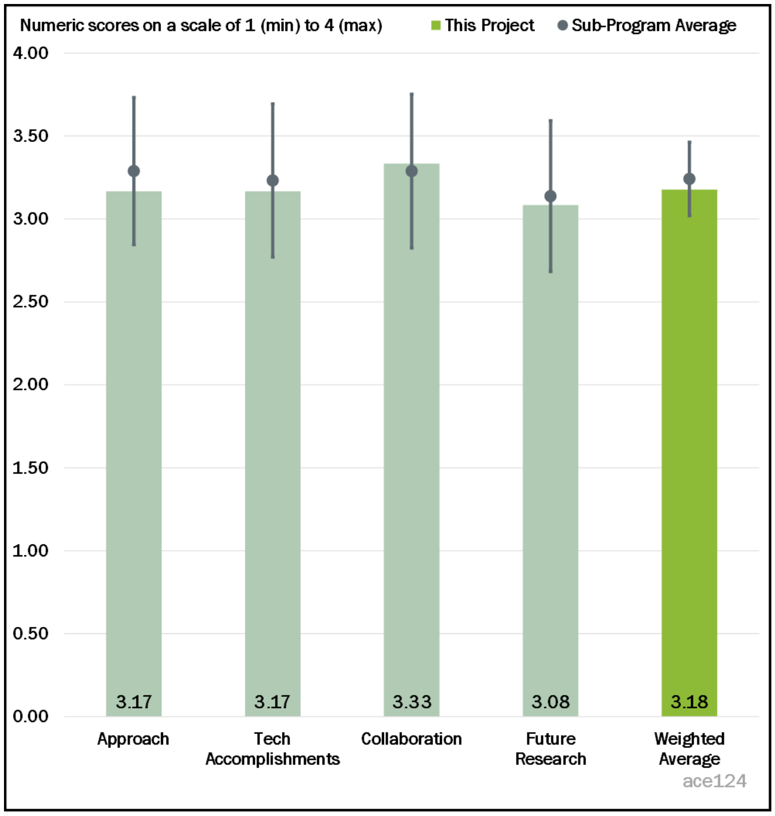

Figure 1-16 - Presentation Number: ace124 Presentation Title: SuperTruck 2 - PACCAR Principal Investigator: Maarten Meijer (PACCAR)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The technologies selected for development are solid, and the approach is sharply focused without extraneous explorations. The progress plan is very clear, and the team members have clear roles. The reviewer appreciated the study of high-risk engine features like thermal swing coatings. The reviewer wished the team good luck.

Reviewer 2:

The program is 1 year later than the other four and has a solid system to subsystem to component level approach. Fleet engagement appears relatively robust, and presenters suggested a customer council that is helping to focus the teams on designs that will be wanted by end users. Some areas of investigation are aggressive that could prove as big wins.

Reviewer 3:

Engine and Powertrain approaches look sound, although not much detail was provided to go on. The reviewer was glad to see some non-conventional technologies being considered. The aerodynamics work was not as clear to the reviewer. Slide 21 shows aerodynamic drag reduction of 20% and 5% on the trailer. So, does this mean that there will be 35% reduction in the tractor aerodynamics to equate to the 60% reduction overall target in aerodynamic improvement?

Reviewer 4:

Some areas of progress can greatly enhance existing vehicles if implemented in production sooner rather than later. Increasing the resistance to heat flow (R-value) of the sleeper cab by 100%, for example, will help reduce heating, ventilations, and air conditioning (HVAC) system loads both while operating and while stationary. This should be a huge benefit toward reducing idle time in both hot and cold environments.

Reviewer 5:
The project demonstrated approaches to attaining or exceeding FOA program goals. The path to the target of 55% BTE clearly identified WHR as required in 2020 AMR slides (also in 2019), but discussion in later (AMR slides and in the question and answer (Q&A) period indicated this team did not think WHR was commercially viable and was pursuing hybrid electric solutions. Clarity is needed on the official path to target. This is a risk item in attaining the FOA goals, and alternatives were not clarified in the project schedule or budget. The progress on design elements appears otherwise sound, especially with this project starting a year after the other projects. A path to commercialization of the various technologies is not well presented, particularly an assessment by the fleet team member of ramifications of the technologies to warranty, service, technician and driver training, facility infrastructure, etc.

Reviewer 6:
The approach that uses the competitor WHR is still highly questionable because this could create an uneven playing field for other competitors. Although PACCAR claims that it is not out of off-the-shelf solutions and the architecture and component sizing are unique, it is hard to imagine that the basic structure would be different, which requires substantial funding and research to reach this basic level. It would be helpful if PACCAR can point out specific differences between PACCAR and its competitor WHR structures.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer found very good progress for this stage of the project, which had a 1 year later start than the other ST2 projects.

Reviewer 2:
This project has a 1-year delay compared to other ST2 projects. The team has made considerable progress in face of a global pandemic challenge.

Reviewer 3:
The project is on track for budget and schedule, even with delays due to COVID-19 related challenges and a schedule start a year behind the other ST2 teams. Use of a functioning mule vehicle demonstrates a level of confidence for final demonstrator project integration. Investigation into ride and handling has been thought of, which is necessary for the significantly evolved configuration. The significant level of software and hardware integrations—including PCC and ACC, mild hybrid systems, and a hybrid electric powertrain—may introduce cost, schedule, and testing challenges in the demonstrator.

Reviewer 4:
The good detail in the efficiency waterfall chart that allows reviewers to understand progress. Key issues seem identified and plans in place for technical accomplishments in the future.

Reviewer 5:
It is too early for the reviewer to get a strong feeling on this question. The aerodynamic gains seem large, but the aerodynamic simulation illustration is clearly not of the SuperTruck vehicle configuration eluded to with the mule photo.

Reviewer 6:
The technical accomplishments are too vague on the engine side, giving the reviewer the impression that no quantifiable improvements have been made at this stage. For example, there is no scale on the y-axis in Slide 9 (Technology Validation) and Slide 20 (Demonstration Vehicle Progress). Furthermore, there is no definite

progress that can be seen or even indicated from all carton-style pictures on Slide 10 (Iterative Simulation and Testing).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The team overall is very strong and the roles are fairly clear. There was a good clarification that the "Cummins" WHR system is still specifically engineered and adapted by PACCAR. It is not a bolt-on part. It is great to have United Parcel Service (UPS) progressive thinking on the team.

Reviewer 2:
A good team has been put together for this project. For the suppliers shown on Slide 23, are they developing new technology for the project, or are they using technology already in production (in another product)?

Reviewer 3:
It would be more helpful if the company logo could be inserted on the slides where those partners have made the contribution to the program, allowing the reviewer to have a better picture of how the partners help the project.

Reviewer 4:
The project team includes a cross section of expertise as desired in the FOA; however, there was no indication on the charts regarding the identity of the trailer manufacturer. Q&A was required to identify the trailer manufacturer, the tire manufacturer is not listed on the first team slide, and no discussion of Crr improvement approaches was included in the review. The involvement of Cummins in WHR was addressed in comments to 2019 AMR, but it is not clear if this project will use WHR in the final demonstrator from Q&A commentary. Aerodynamics work involving 1/8- scale and ½- scale models suggests there were wind tunnel investigations with further partners and suppliers, which were not described in the presentation.

Reviewer 5:
There is a strong list of partners and great strategic areas. The reviewer was puzzled why Stoughton Trailers was given credit verbally for their development work on trailers, but they were completely left off the list of collaborators.

Reviewer 6:
The reviewer commented that some more evidence and examples of efforts that collaboration has proven successful were needed. There were 135 people in attendance that could all benefit, and the reviewer expected to learn how teamwork could increase success for projects like these. The reviewer was disappointed that none of the SuperTruck teams offered much on collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer appreciated the summary slide of future work. The overall plan is very solid and explained well.

Reviewer 2:
The proposed work for the upcoming year looks good. At this stage of the project, the reviewer hoped to see significant progress toward demonstration of the proposed technologies in the mule vehicle next year.

Reviewer 3:
Plans are in place and the team is committed, but there appear to be some components that are behind in definition that might put the project at risk. The reviewer commented that a list of corrective actions even at a high level would have helped.

Reviewer 4:
The reviewer said that the proposed future research in Slide 25 covers most of the challenging issues.

Reviewer 5:
Building of the mule 2.0 with mild hybrid and battery retrofit has the opportunity of reducing schedule risk if the software and hardware integration is representative of the final demonstrator and can possibly be carried over. The WHR system is included as a FY 2021 engine future work, but the OEM also discussed that it was not commercially viable; this places budget and schedule questions with respect to attaining goals. Market evaluation of technologies for near-term commercialization is also needed but not clearly identified as a future deliverable; this is particularly needed due to a significant revision in vehicle configuration from existing baselines. While comparison to 2009 progress is inherent in ST2 FOA goals, commercial viability with respect to current model year performance and cost models is relevant and necessary and should be included in planned work.

Reviewer 6:
The reviewer was concerned about the production viability of an MX11 engine with new technologies and complexities buried deep underneath a cab and sleeper. The reviewer was willing to wait for next year's reviews to see their "secret access panels" mentioned in the Q&A. This did not strike the reviewer as being deemed production acceptable to fleet customers, but we will know in 12 months.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is relevant to DOE objectives as described in the FOA and with respect to future freight industry needs. The system approach including a wide range of technology solutions provides a level of robustness to the potential utility of the concepts, especially where this project diverges from the four other ST2 projects, such as the radical aerodynamic shaping of the cab and investigating alternatives to WHR.

Reviewer 2:
This project directly supports the DOE VTO program goals of high freight efficiency for the U.S. marketplace.

Reviewer 3:
All aspects of the work are sharply focused on the goals and barriers and offer promise of improved economics and efficiency for freight movement.

Reviewer 4:
Class 8 HD tractors use the most fuel and create a majority of GHG emissions from commercial trucks. It is critical that DOE continue investments in HD on-road vehicle development.

Reviewer 5:
Some areas of development ideas seem questionable while others seem extremely valuable.

Reviewer 6:
This project supports the overall DOE objectives if it is able to achieve 55% BTE and greater than 100% improvement on the vehicle.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that the project looks good and is staying on schedule.

Reviewer 2:
It appears to the reviewer that the project team has all it needs to complete the program.

Reviewer 3:
Resources seem sufficient, but an exhibit explaining areas of concern with resources would be good.

Reviewer 4:
The reviewer gave the benefit of the doubt given a late start and COVID-19 timing challenges.

Reviewer 5:
A general suggestion is for future advanced MHDV development to shift resources more toward technology discovery and fewer resources to full on-road demonstration.

Reviewer 6:
The project started in 2017, approximately a year behind other ST2 programs. The 2020 AMR reports 53% complete and reported funding of $13.0 million in 2019 and $16.7 million in 2020. The 2019 AMR reported 2018 funding of $5.7 million and 2019 funding of $13 million. The FY 2018-2020 estimates sum to $35.4 million out of a $40 million budget, but the project is reported as only 53% completed in AMR 2020 with work projected to complete in 2022. The project discussed only minimal impacts from COVID-19 related manpower and procurement challenges. Inadequate detail of the program budget with respect to resources and schedule was provided to properly assess the sufficiency of the project.

Presentation Number: ace128
Presentation Title: Reduced Precious Metal Catalysts for Methane and NOx Emission Control of Natural Gas Vehicles
Principal Investigator: Michael Harold (University of Houston)

Presenter

Michael Harold, University of Houston

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

All reviewers indicated that the project was relevant to current DOE objectives and that the resources were sufficient.

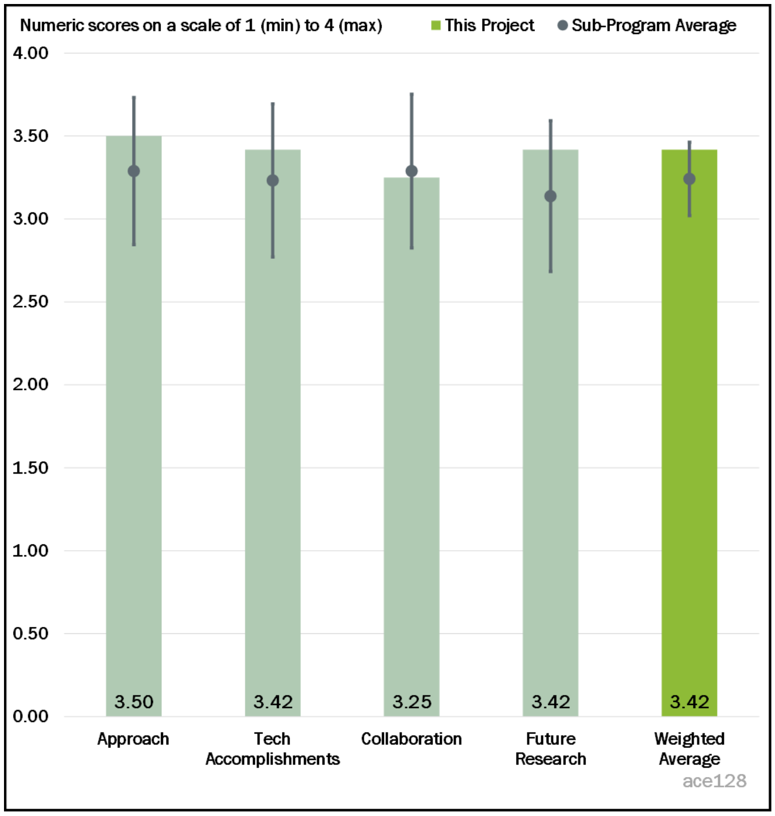

Figure 1-17 - Presentation Number: ace128 Presentation Title: Reduced Precious Metal Catalysts for Methane and NOx Emission Control of Natural Gas Vehicles Principal Investigator: Michael Harold (University of Houston)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project is very well designed from a technical standpoint. The progression from density fuel theory (DFT), to mechanistic studies, to bench-scale testing, to model development, to prototype testing is impressive.

Reviewer 2:

The reviewer asserted that the approach is sound, and work has been distributed between collaborators to address all milestones.

Reviewer 3:

The presentation and project did a nice job of making the case for the context of the work in four-way catalysts (FWCs). The approach taken seems very reasonable and the interplay within the project of theory/experiment is clear. The group, while perhaps ambitious in its scope of work, is pursuing logical aims with no gaps readily identifiable.

Reviewer 4:

The project has a well-rounded approach to promoting three-way catalysts for reducing precious metals for natural gas vehicles. The study is fundamental in nature, focusing on laboratory-scale evaluation of catalysts.

Reviewer 5:

Although the approach here to use spinel supports for CH_4 oxidation is intriguing, CNG catalysts are not highly sought after by LD OEMs due to their focus on TWC and diesel powertrains. However, the catalyst optimization work done here and the degree of learning from the analysis is critical to arriving at a viable catalyst solution.

Reviewer 6:
The mixture of modeling and experiment is very important in guiding the direction of this project. The impact of modulation was shown last year but is explored more here. The inclusion of sulfur in the testing is important. Water—a typical poison—is included in all feeds.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Milestones seem to be on track for a project a little more than halfway through its cycle, though the reviewer agreed with prior comments regarding the ambition of the work. Overall, the team seemed to address the majority of comments from a prior review sufficiently. No aspect of the project seems to be lagging appreciably. The two publications from the work are nice and seem like the appropriate venue for some of the joint theory and experimental work.

Reviewer 2:
Many catalyst formulations using spinel supports have been investigated and reported in this work. From that activity, the most promising candidates have been down-selected for further analysis and understanding. This is necessary to derive the best catalyst for an application. The modeling and formulation effort is well thought out and works well together in this project.

Reviewer 3:
A lot of progress has been made since the first year of the proposal. New spinel compounds were found that contribute to improved activity. The modulation may mediate the impact of sulfur. There are many directions of work to check out, requiring good collaboration between the laboratories on the different directions.

Reviewer 4:
The results showed good progress with promoting low-temperature CH_4 and NO_x removal. Scaled-up evaluation of parts in a real exhaust stream would provide further insight into the performance of the new technologies being evaluated.

Reviewer 5:
New spinel is identified through screening. However, it is not obvious if the desired light-off and cost targets (that are not presented) can be achieved or were achieved with the identified formulations. Such estimations will be needed for evaluating the technical accomplishments; otherwise, the judgment would be based on qualitative interpretation.

Reviewer 6:
The project looks to be progressing on schedule. The modeling results show good agreement, the experimental results are intriguing, and the reviewer looked forward to further elaboration on the mechanisms at play. Not to nitpick, but the presentation of the budget period 2 (BP2) go/no-go decision is confusing (and probably a copy-and-paste error). The decision point is "Identification of a candidate material complete," and the description refers to modeling progress. It can be inferred that this was meant to refer to the modeling effort and that the Go/No-Go was answered in the affirmative.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer found a good balance of fundamental to applied research among the collaborators in addressing the objectives.

Reviewer 2:
The team of collaborators on the project is excellent at University of Houston, University of Virginia, ORNL, and Clean Diesel Technologies, Inc. (CDTI). They have good contacts with OEMS but might consider a direct interaction with a company making NG engines.

Reviewer 3:
The collaboration slide, while detailing well the various work components, did not delineate who did what, i.e., what were the specific contributions spread across the various partners. A separate slide showing a discrete example of how the team worked together on each component of the work would have been powerful in convincing reviewers the project team provides a sum greater than the parts.

Reviewer 4:
The project appears to be well coordinated with cooperation across the participants. Some indication of which work was led by which party would be helpful. It looks like the heavy lifting was done primarily by the University of Houston.

Reviewer 5:
The reviewer commented that this is a good R&D collaborative effort. It would benefit from the inclusion of an LD OEM for guidance.

Reviewer 6:
Collaboration appears good with commercial catalyst partner providing materials for evaluation. Further collaboration with a clear path toward commercialization would improve the likelihood of program success.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The additional work proposed will help clearly identify a best option to move forward. The modeling work will also help in the process of selecting the best catalyst.

Reviewer 2:
In general, the path forward for the project is evident and continues on the work already initiated.

Reviewer 3:
The proposed future work should provide insights into the mechanistic behaviors as well as the durability of the catalysts developed.

Reviewer 4:
Fundamental and application challenges will be addressed in the proposed future work.

Reviewer 5:
The future work is well planned and sensible. It is difficult to tell if decision points or alternative development pathways are implemented.

Reviewer 6:
The directions of the future research are quite varied, especially in the experimental area. The inclusion of another Pt/Pd ratio than 19:1 could be considered, while being wary of the potential negative interactions between Pt and Pd. The important role of partially oxidized Pt could be studied further, along with how it is affected by S. With the importance of modulation determined, the Spaci-MS work can be very useful for understanding the mechanism of the reaction through the catalyst. The project does not need new avenues to

explore. With all of the project feeds having large amounts of water, one wonders if a few experiments, with very small amounts of water or no water, would comment on the mechanism in a useful way.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer commented that the project absolutely supports the overall DOE objectives. The team has carefully considered how the work fits into the greater context of VTO DOE goals and clearly contributes to reducing PGM content. The team should get particular kudos for attempting to integrate base-metal derived materials. Too often the focus is on reducing PGM loading only rather than approaching the problem from materials discovery. As such, the work resides in an excellent niche very suitable for VTO projects.

Reviewer 2:
Yes, this project focuses on reducing emissions from internal combustion engines.

Reviewer 3:
Lowering of the light-off temperature is clearly important pathway for NG aftertreatment, which the new catalysts here may do. This clearly supports DOE objectives for this system.

Reviewer 4:
This project could potentially accelerate the adoption of stoichiometric natural gas vehicles while reducing their GHG emissions. Considering the natural gas production capacity of the United States, this would help reduce U.S. dependence on foreign energy sources.

Reviewer 5:
Low-temperature methane oxidation catalysts are needed to decrease fuel economy (FE), reduce dependency on foreign oil, generate low-cost systems, and lessen dependency of rare-earth and Pd metals.

Reviewer 6:
Although the catalyst development approach is relevant for innovating new technologies in this area, the use of CNG catalysts is not at the top of the list for LD OEMs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The provided resources appear to be satisfactory to provide high probability of success for the program.

Reviewer 2:
All resources seemed appropriate to the reviewer and in place for timely completion of the work.

Reviewer 3:
The project appears to have sufficient resources to achieve project goals.

Reviewer 4:
The testing and evaluation capabilities of the University of Houston, University of Virginia, and ORNL groups on this project are sufficient.

Reviewer 5:
The collaborators have all the tools and resources needed to effectively execute the project.

Reviewer 6:

The reviewer affirmed that this project seems well funded. It looks like about half of the federal funding remains for the last year of the 3-year project. As this phase, which includes costly engine testing, this is not surprising.

Presentation Number: ace129
Presentation Title: Design and Optimization of Structured Multi-Functional Trapping Catalysts for Conversion of Hydrocarbons and NOx from Diesel and Advanced Combustion Engines
Principal Investigator: Michael Harold (University of Houston)

Presenter

Michael Harold, University of Houston

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

All reviewers indicated that the project was relevant to current DOE objectives and the resources were sufficient.

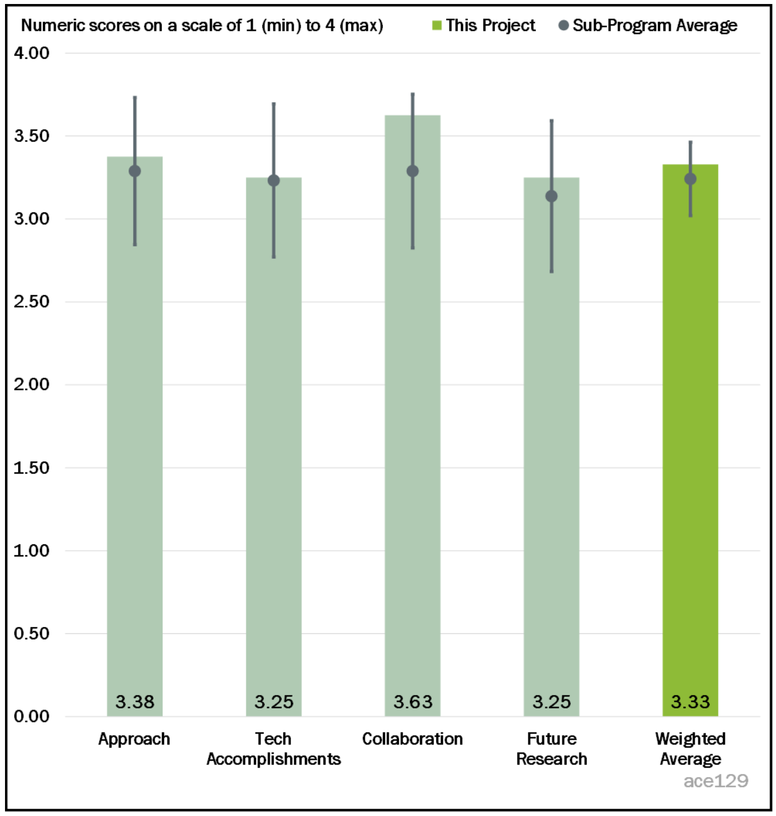

Figure 1-18 - Presentation Number: ace129 Presentation Title: Design and Optimization of Structured Multi-Functional Trapping Catalysts for Conversion of Hydrocarbons and NOx from Diesel and Advanced Combustion Engines Principal Investigator: Michael Harold (University of Houston)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This is a well-designed approach to addressing low-temperature NO_x and HC emissions. The progression from the molecular-level modeling through full-scale prototyping is ambitious and impressive.

Reviewer 2:

The objectives and approaches were clearly defined, and work was done to address the milestones.

Reviewer 3:

With the onset of Tier 3 and low-emission vehicle (LEV) III emissions standards, many novel approaches will require investigation to help ensure that viable catalyst aftertreatment system solutions are available to OEMs for their vehicle fleets. All these solutions have the common requirement of low-temperature catalyst performance in order to make sure the catalyst system will function at a high enough level during cold portions of the drive cycle to meet SULEV 30 and Bin 30 emissions standards. The approach in this project offers this capability if executed properly. Employing the trapping technology proposed here is one way to achieve this requirement. The system approach presented in this work is an innovative way of capturing the functionality of both HC and NO_x trapping at very low temperature together with an oxidation element to achieve the desired conversion efficiency of those species for a lean, advanced combustion mode. Incorporating modeling to predict the performance is also a requirement for optimizing the solution.

Reviewer 4:

The presentation and project did a nice job of making the case for the context of the work into multifunctional trapping catalysts. The approach taken seems very reasonable, and the interplay within the project of theory and experiment is clear. The group seems to have made significant progress to converge much of the work to the current point. The way forward is clear.

The work clearly demonstrates knowledge gained about the various components of the system, but the connection of a direct improvement in performance is not so evident. While the candidate materials have been identified, how close is the system to the desired metrics? A more goal driven approach could have benefited the project, since the integrated system must achieve certain performance standards.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The incorporation of modeling with catalyst development is a desirable combination to down-select candidate catalyst formulations and architectures in a more time efficient manner. The methods used in this project to narrow down the catalyst field are appropriate and effective. The inclusion of multiple catalyst architectures to derive the best outcome is an essential component of this work and is well conceived. Finally, employing combinations of promising catalyst technologies to achieve the required overall functionality is appreciated. Many times, system considerations are not addressed.

Reviewer 2:

Milestones seem much closer to being on track to achieve the overall goals of the project than in the prior funding period. The team seemed to address the majority of comments from the prior review sufficiently. No aspect of the project seems to be lagging appreciably, though the HC trapping portion seems like it has less emphasis relative to some of the other parts. The project appears to be converging at the critical time to assess the system level performance.

The project is very productive based on the number of publications produced from the work.

More focus or at least clearly identifying the gap between the current system and the desired metrics would have been beneficial.

Reviewer 3:

Milestones were addressed but it was not obvious to the reviewer how far the technical and non-technical barriers were addressed and accomplished. For example, there are about four to five flavors of different formulations for PNA identified. What criteria are considered or will be considered for identifying pros and cons of these different formulations, especially if they have to be integrated with other functions and components? Also, how do these different functions, if they have to be integrated into one device, impact the performance of PNA and vice versa? Also, the empirical evaluations carried out so far did not address any practical viability of these technologies. The same applies to HC traps and oxidation catalysts (OC).

Additionally, no quantified targets (e.g., NOx, and HC storage) were proposed; so, it was difficult to evaluate progress against such potential indicators. Going forward, such targets (obviously these will be estimates the PI has to come up with industry partners) should be proposed, and the technical accomplishments should be compared against these measures. The above are examples, but the PI and collaborators have to come up with such indicators.

Reviewer 4:

Good progress has been made, and the BP2 milestones have been met. However, it seems like the project overall may be running behind, as 70% progress is reported with about 5 months remaining. Completing the project on schedule appears challenging, though this is likely attributable to the pandemic situation to some extent.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project appears well coordinated with cooperation across academia, industry, and the labs.

Reviewer 2:
The participant level in this project brings together diverse technical strengths to address all the aspects of the project. This will help ensure a successful outcome.

Reviewer 3:
The assembled project team seems to contain all the needed parts with defined theory/synthesis/catalyst testing/industry buy in. Some additional discussion of the industrial partners' roles, and how these evolve when the group shifts to evaluating the integrated system performance, would have been beneficial.

Reviewer 4:
The reviewer commented that it would have been outstanding if the contributions from industry partners were clearly shown.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The future of the project is clear and continues on the work already initiated. The next period of work is critical to assessing if the project will meet the desired goals.

Reviewer 2:
Although much work remains to be completed, focusing on integrating the different catalyst technologies to produce a viable aftertreatment system and testing its performance under "real world" conditions is appropriate and necessary.

Reviewer 3:
The future work is well planned, though it seems difficult to complete the work in the time remaining for the project. This may have to be addressed through a no-cost extension.

Reviewer 4:
The future work did not define the following: practical challenges, such as chemical poison impacts, which are critical for the viability; and other durability challenges that can be encountered in practical applications. It is not expected to evaluate under all durability conditions, but the PI and collaborators must consider critical factors when evaluating under simulated conditions. Especially, such must be considered as a part of pre-conditioning the catalyst.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer commented absolutely. The team understands how the work fits into the greater context of VTO DOE goals, the value of an integrated catalyst design, and the thinking about improving both individual components of the system and optimization of the whole.

Reviewer 2:
This work aims to reduce cold-start HC and NO_x emissions, possibly allowing for increased fuel economy. This is directly relevant to the DOE mission.

Reviewer 3:
This activity supports USCAR advanced engine combustion initiatives that need a feasible aftertreatment system as part of the powertrain.

Reviewer 4:
Low-temperature conversion of all the proposed pollutants poses a major challenge to the cost of the systems, fuel economy and therefore more GHG, and real-life emissions control. This project is much closer to addressing practical challenges faced today and expected in the future.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
All resources seem appropriate and in place for timely completion of the work.

Reviewer 2:
Among the collaborators, diverse tools and capabilities are available to make this project successful.

Reviewer 3:
The resources for this project appeared to be sufficient to the reviewer.

Reviewer 4:
The reviewer had no issues.

Presentation Number: ace130
Presentation Title: Development of Passive Hydrocarbon/NOx Trap Catalysts for Low-Temperature Gasoline Applications
Principal Investigator: Mark Crocker (University of Kentucky)

Presenter

Mark Crocker, University of Kentucky

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

All reviewers indicated that the project was relevant to current DOE objectives. They also indicated that the resources were sufficient.

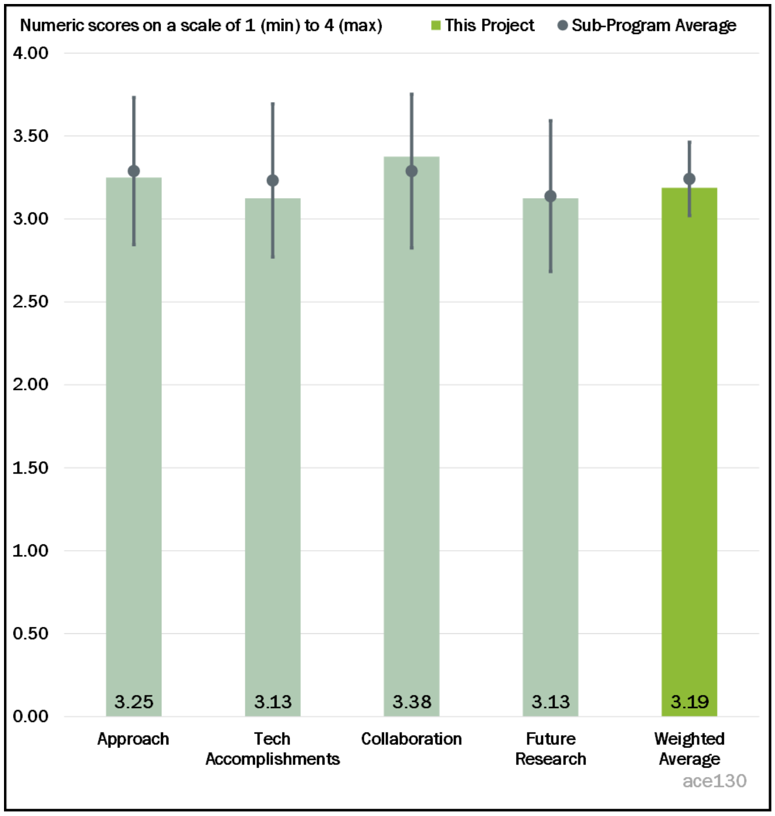

Figure 1-19 - Presentation Number: ace130 Presentation Title: Development of Passive Hydrocarbon/NOx Trap Catalysts for Low-Temperature Gasoline Applications Principal Investigator: Mark Crocker (University of Kentucky)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The work appears well designed, with a solid combination of characterization, experiment, modeling, and computational studies. This span from fundamentals to practical application is always impressive.

Reviewer 2:

The presentation and project identify key technical barriers and provide strategies to understand structure-activity relationships as many different parameters are studied (impact of water, aluminum [Al] content, etc.). The presentation was of high quality, and the Q&A provided an honest assessment of the project's status.

Relative to other projects, this one seemed less metric driven. While the studies performed were well crafted and carefully executed and new knowledge of the systems studied is clear, it was not evident to this reviewer how the knowledge gained is directly informing catalyst design in the final stage of the project. That connection was missing.

Reviewer 3:

The project team is focused on improving low-temperature NO_x control by using passive NO_x adsorbers. Barriers listed also include low-temperature hydrocarbon control. The characterization of the passive NO_x adsorber materials and reaction chemistry are critically needed to not just better understand them, but to also address the degradation modes. These materials were growing in interest a few years ago as potential solutions to cold-start NO_x control, but since have been plagued with deactivation issues. A regeneration strategy to reactivate their ability to adsorb NO_x is critical if they are to be possible solutions. The team is addressing that challenge through careful synthesis, characterization, reaction testing, and modeling.

Reviewer 4:
Technical targets must be defined and must be quantitative: for example, 0.1 g NO_x storage-release/1 g catalyst, between 50°-200°C, etc. Such definition will help to take or change project decisions and directions as and when needed. Similarly, if possible, barriers must also be quantified. Significant work was completed but not having the above quantified/semi-quantified targets made it difficult to estimate percentage targets achieved to address the barriers and challenges.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Good progress has been made, but the 2020 milestones appear to be behind schedule, and a great deal of work is planned by the end of the project even with a 3-month extension. This is understandable given the current situation with the pandemic, but the timing seems tight.

Reviewer 2:
The studies outlined in the presentation are very detailed and provide a clear knowledge gain into the factors that impact catalytic activity. The response to prior questions seemed appropriate. The milestones were not as discrete as for most applied projects. Also, given the group of researchers involved and the amount of fundamental studies presented, it was very surprising to the reviewer to see no more than a single publication submitted on this work, as it seems to align well with dissemination in journals. It also seems a missed opportunity to have only just started applying the knowledge gained in the first 2 years of the project to real automotive scenarios.

Reviewer 3:
The team has been studying both Pd/SSZ and Pd/BEA. It concluded that the latter is less interesting due to more challenging degradation issues. The team has verified CO-induced deactivation of these materials and has been evaluating these materials to determine which Pd species are important. It is also trying to identify the "right" Pd species to have in the zeolite to ensure trapping and regeneration through multiple cycles. The team showed a variety of characterization data for ion-exchanged Pd^{2+} species in the starting catalyst. CO diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS) suggests a wider variety of species exist during operation, including non-ion-exchanged species. Modeling suggests a Pd+H species as the key NO_x trap site. The team has shown the ability to make zeolites with different Al pairings such that they can maximize or minimize the distribution of certain Pd species. All of these contribute to a better understanding of the reaction chemistry and therefore making a working, passive NO_x adsorber. Convergence in the results as to what species to target for synthesis, and which are lost via deactivation, is not clear, however.

Reviewer 4:
The work done was described under technical accomplishments. However, "accomplishments against the targets/milestones" were not obvious, especially how all the work done and the outcome are tied to a specific objective. Below are some additional details:

Due to the nature of the project and multi-pronged approach taken, the technical information provided is exhaustive: however, it was difficult or not possible to connect all the technical pieces to see a big picture, especially how all of these are helping to come up with a potential solution. A slide that shows the walk/approach toward achieving the goal would have been useful.

A comprehensive approach was taken (multiple characterization techniques used, model and the catalysts that appear to be fully formulated, and performance, durability and modeling techniques). However, it is not obvious how all these insights gained from the above sites are driving to develop a new formulation. It appeared that a generic statement was made indicating paired Al sites will be prepared. However, there were no insights on whether such sites improve performance or durability, etc., or how the catalyst manufacturer and application OEM would be helped with taking steps that would not have been done without this project.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project appears to be well coordinated, with participants from industry (OEM and catalyst supplier), academia, and the National Laboratories.

Reviewer 2:
This is an unquestionably a top-notch group of scientists who are well positioned to make progress in this area. The interaction is clear, given the wealth of data regarding catalysts synthesis, performance, and characterization. Some of the skill sets of researchers is duplicated (Bell and Gounder, in particular). Having a dedicated, theory PI also seems like a missed opportunity. Some of the team (involved with vehicle modeling effort) seems to have been underutilized to this point on the project.

Reviewer 3:
There is obvious collaboration within most of the team. The only missing evidence from the presentation was the role BASF plays. All other team members had obvious contributions.

Reviewer 4:
The contribution to technical work from the industry collaborators were not obvious. Are they just consultants?

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The future work is well planned and progresses logically, but there seems to be a lot planned in the next 5 months. As stated by the presenter, the work on regeneration seems of particular importance, as cyclic degradation is a critical barrier to practical implementation. It may make sense to incorporate this into a decision point.

Reviewer 2:
The planned studies seem appropriate. As discussed above, reserving the more applied tests until the end of the project seems a missed opportunity. Some of the practical aspects of testing may have permitted additional fundamental studies in a feedback loop, if more time were available.

Reviewer 3:
It appeared a generic statement was made indicating paired Al sites will be prepared, but there were no insights on whether such sites improve performance or durability, etc., and how they will help the catalyst manufacturer and application OEM in taking steps which they would have not done without this project.

Reviewer 4:
The focus on synthesizing the “right” Pd species is appropriate, but the challenge remains: the degradation and how to stop it. That aspect should be the primary goal (“development of a viable regeneration strategy”). Although finding a surrogate for Pd would be nice, there is an inherent assumption that the periodic table has been tried by the catalyst manufacturers (for this zeolite system) and Pd will remain as the best candidate. Thus, the focus should still remain on a regeneration strategy. What those regeneration strategies look like was not made clear.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project aims to reduce cold start emissions, which is directly relevant to the DOE mission.

Reviewer 2:
Work is relevant to address one of the key challenges—low-temperature NO_x control—which is a major bottleneck leading to expensive systems, more CO_2 emissions, etc.

Reviewer 3:
The reviewer commented absolutely. It is clear the team has carefully considered how the work fits into the greater context of VTO DOE goals. At this stage, it is less clear how the knowledge gained to date from the project has impacted industrial catalyst design from a metric-driven perspective.

Reviewer 4:
Passive NO_x adsorbers gained wide interest several years ago and remain interesting. These would alleviate cold-start issues and enable low-temperature combustion modes. But, the degradation of these systems remains the problem to overcome. A solution would be very impactful.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
All resources seem appropriate. All needed components to finish the project are in place, particularly the excellent industrial collaborations.

Reviewer 2:
The resources seem appropriate for the milestones over the project term.

Reviewer 3:
Among the collaborators, the resources needed for executing this project appear sufficient.

Reviewer 4:
Resources for this project appear to be sufficient.

Presentation Number: ace135
Presentation Title: Toward Predictive Nozzle Flow and Combustion Simulations for Compression Ignition Engines
Principal Investigator: Gina Magnotti (Argonne National Laboratory)

Presenter

Gina Magnotti, Argonne National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 50% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

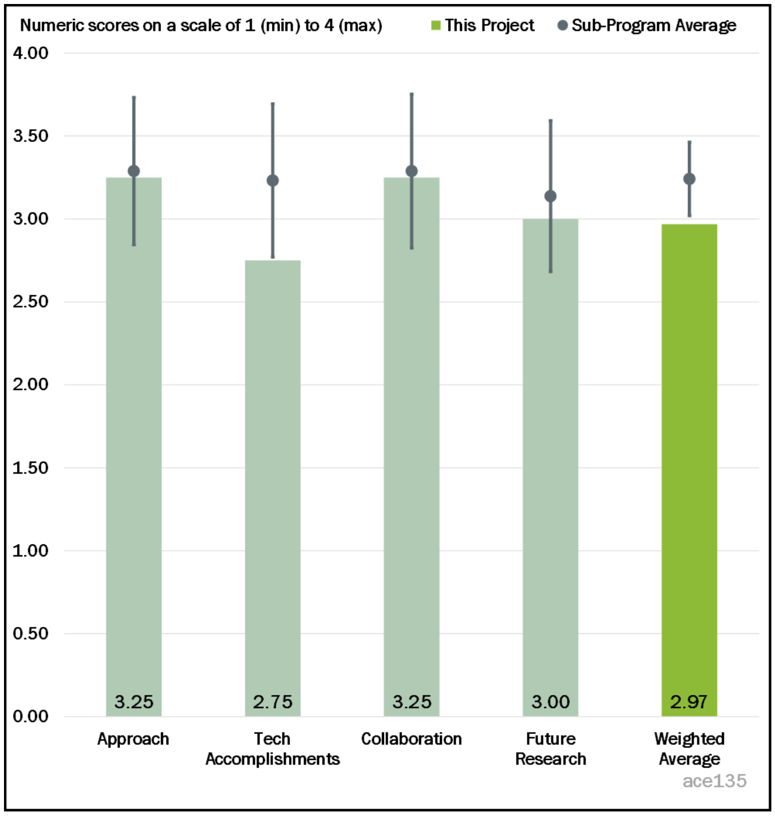

Figure 1-20 - Presentation Number: ace135 Presentation Title: Toward Predictive Nozzle Flow and Combustion Simulations for Compression Ignition Engines Principal Investigator: Gina Magnotti (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted a fundamentally-sound approach to develop simulations tools. This would be done by leveraging experimental data from various real-world application sources as well as the step sequence to achieve project goals from developing physics-based models to identify bottlenecks and ways to improve scalability of solvers and CFD codes.

Reviewer 2:

The project team addresses the barriers outlined by DOE and the several areas of engine combustion research needs by developing various sub-models, which are validated against data from the collaborators. The project will be improved if it is devoted to exploring the simpler, feasible, transferrable technologies for the engine combustion community.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Solid progress has been made in this project as indicated by the healthy list of accomplishments summarized in the project review.

Reviewer 2:
Technical progress and accomplishment on this project continue to move the understanding at a good pace while this project has been ongoing for a long time. Over time, the project has focused on the development of various sub-models, which requires a very high-performance computational capability. Such sub-model complexities and high-performance computation need may be difficult for engineers to use those tools effectively and to transfer good knowledge to the engine community. These issues need to be addressed.

For the multiple injection study, the flame stabilization mechanism is important for low-temperature combustion through the level of premixed since a majority of flame under LTC will impinge on the wall due to the longer ignition delay and a significant amount of combustion recession may decrease combustion efficiency substantially. The difference in the effects of the cavitation flow versus transient flow on spray structure when the flow rate is highly fluctuating is not clear. This area needs more effort for scientific understanding, modeling, and technology. The reviewer believed that the project focuses on the simple, accessible, reliable, design tool development with a fast turnaround time.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer called the collaboration work between academia, the National Laboratories, and industry partners fantastic and w. ell done!

Reviewer 2:
The collaboration level seems to be good, and the PI collaborates with a lot of groups within Argonne National Laboratory (ANL), with the National Laboratories, university, industry, and a foreign national university. However, the reviewer had concerns that most work was done with specific software, CONVERGE, which has very limited flexibility and diversity. The reviewer also expressed concerns about the lack of educational transformation of technology to industry and academia while the academic participation is not as strong as the industry participation.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The PIs have listed the remaining challenges and barriers as well as proposed future work with the desire to leverage expertise and resources from the partners but no concrete plans on the development pathways. The research nature of this work is understood.

Reviewer 2:
The reviewer realized that the project is in its final year according to the ACE135 presentation (starting in 2012 and ending in 2020). The future plan seems to be the extension of the current work with the production of a large amount of data and their comparison with CFD model. No specific sub-models to bridge the gap between experiment and CFD performances are suggested. The reviewer would have liked to see how to handle the large amount of experimental data together with simulation data and the method to reduce the computational time. The detailed future plan involves further improvements to their models, including the cavitation erosion model, flamelet model, and ignition model. The team has planned model validation and also plans further extending the models to different applications. The research plan is feasible, but it needs a lot of resources.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer commented yes, this project supports the overall DOE objectives because it is aimed at addressing a major industry pain point or a need for a robust simulation tool to predict engine performance and emissions.

Reviewer 2:
The project is relevant to the DOE goals of the accuracy improvement and efficiency of the simulations. The reviewer indicated that the modeling capability is needed to address short simulation turn-around time.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project team has sufficient resources.

Reviewer 2:
The funding level has been consistent over the years for the duration that this project has been active.

Presentation Number: ace136
Presentation Title: Medium-Duty Diesel Combustion
Principal Investigator: Stephen Busch (Sandia National Laboratories)

Presenter

Stephen Busch, Sandia National Laboratories

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

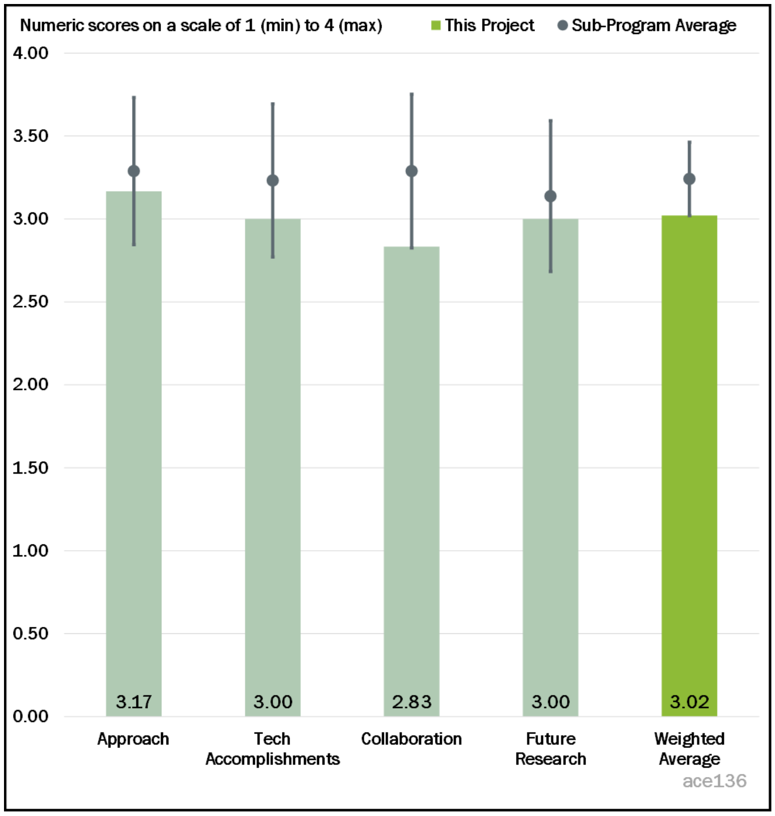

Figure 1-21 - Presentation Number: ace136 Presentation Title: Medium-Duty Diesel Combustion Principal Investigator: Stephen Busch (Sandia National Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach of this project—to identify and address the sources of toxic emissions along with looking at cold-start emissions—is sound. The optical engine provides an excellent tool to investigate the in-cylinder details, and the metal engine should provide proper validation to the optical engine results. There is also a good mix of simulation and experiment to accelerate progress.

Reviewer 2:

Leveraging insights from experiments to develop and evaluate novel approaches to CFD spray modeling for the catalysts heating operation, as well as leveraging experiments and in-depth analyses to develop and test hypothesis for the piston bowl geometry study, are fundamentally sound approaches.

Reviewer 3:

The project scope identifies the research priorities for mixing-controlled compression ignition (MCCI) as the reduction of engine-out NO_x and reduction of cold-start emissions. Work highlights the study of spray-wall interactions and catalyst heating as pathways. The project is setting up a MD engine to validate the concurrent work on new bowl studies and CFD models to capture the catalyst heating physics. The project could benefit from a review of common approaches on SI/CI used in modern catalyst heating. Also, similar bowls have been considered in the past; the results from this work may prove too valuable in assessing the benefits/challenges associated with the new geometry proposed, increased surface areas, and disruption on the large-scale motions.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
This project has made some significant progress in the relatively short period of time that it has been running. The optical examination of late-cycle injection and the presence of HC in the piston bowl is insightful. The improvement in the modeling of this process is also good. The development of the dimple step-lipped (DSL) piston should be interesting as the project moves forward. The link to catalyst heating will be important to establish, since this is a major thrust of OEMs for a variety of reasons. It will be very important to link the detailed work with the overall performance of the engine from an efficiency and emissions point of view.

It would also be beneficial for this project to be included in Co-Optima (or its successor program) going forward. The experimental setup and work here would be subject to differences in fuel properties as well, which would be of significant mutual benefit to Co-Optima and this project.

Reviewer 2:
Limited progress was demonstrated for this reporting period and slow progress in the laboratory due to the COVID-19 pandemic was established as the root cause during the project review. It will be helpful to start putting some points on the board to establish some confidence that the project objectives will be achieved. For example, no results from the catalysts heating operation have yet been demonstrated at the mid-way point of this 3-year program.

Reviewer 3:
It appears that the program has experienced delays in meeting some of their key deliverables, with respect to the complete engine shakedown and pollutant emissions and catalyst heating work. It may be useful to describe the test space of injection strategies (work from 2019) and how this has been carried forward. No indication is provided regarding the chemistry in the catalyst. The strategy on the catalyst is a bit unclear. There is discussion of unburned hydrocarbon (UHC) reduction and their use for catalyst heating. What is the direction? There has been a lot of work from 2016 to 2020 on piston and injector imaging. Has any of this work been consolidated in specific models or laws that may be used across broader applications?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There was reasonable collaboration between the Sandia National Laboratories, Ford, and the Wisconsin Engine Research Consultants.

Reviewer 2:
Work by project partners is indicated throughout the presentation.

Reviewer 3:
The collaboration and coordination among project partners appear to be good. However, this project appears to be operating a bit in a vacuum with respect to other Advanced Combustion Engine (ACE) projects in the DOE portfolio. It would be helpful to seek some collaboration with other MD/HD MCCI projects that may lend some insight into issues facing this project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The future work appears appropriate—the metal engine is close to commissioning and this will be very important to validate the optical engine results. The influence of the (DSL piston upon efficiency and the subsequent impact upon emissions (particularly NO_x) will be critical for this project.

Reviewer 2:
The future work may be enhanced by tying the UHC, the heat release trace (experimental and simulation), and the catalysis heating. Will there be work dedicated to the catalyst chemistry?

Reviewer 3:
The sequence of experimental and analysis tasks outlined in the roadmap for both the catalyst heating operation and piston bowl geometry are reasonable, but enough progress has not yet been demonstrated to provide the confidence that the project objectives will be achieved by the end of the 3-year program. The lack of an engine control unit (ECU) that automatically compensates for the pressure waves in the rail is a concern that should be addressed. The researchers may also want to look at multiple pilot injections and multiple post injections.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project directly supports the DOE goal of examining opportunities for MCCI engine efficiency improvement and emissions reduction.

Reviewer 2:
Yes, this project supports the overall DOE objectives because it will help to improve our understanding of fuel injection, air motion, and combustion chamber geometry effects on combustion and pollution formation, which is a critical enabler for the development of fuel-efficient diesel engines that will comply with low emissions regulations.

Reviewer 3:
The overall work is relevant. Relevance could be improved with a better visibility with respect to engine-like conditions and catalyst engine in-and-out emissions analysis. Hopefully, this will be the case as the engine comes online.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
It appears that the resources are sufficient for the project goals and timeline.

Reviewer 2:
The reviewer affirmed resources appear adequate.

Reviewer 3:
The reviewer was not sure how much of the budget for this 3-year program is left ,but the limited progress demonstrated at the mid-way point albeit due to extenuating circumstances with the COVID-19 pandemic left the reviewer with the impression that sufficient funds should still be left.

Presentation Number: ace138
Presentation Title: Partnership for Advanced Combustion Engines (PACE) - A Light-Duty National Laboratory Combustion Consortium
Principal Investigator: Paul Miles (Sandia National Laboratories)

Presenter

Paul Miles, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers indicated that the resources were sufficient, 20% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

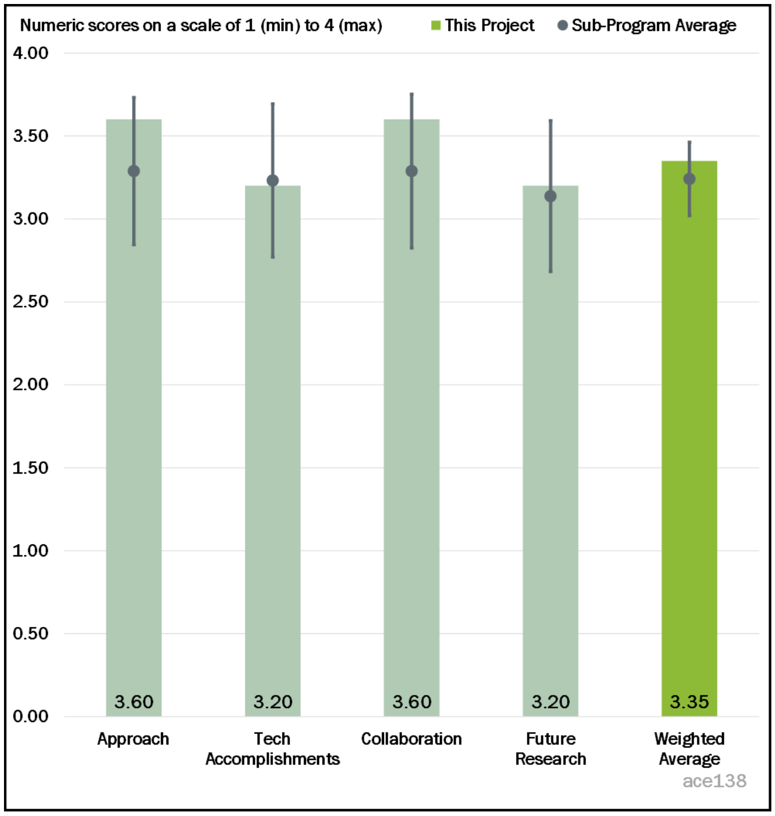

Figure 1-22 - Presentation Number: ace138 Presentation Title: Partnership for Advanced Combustion Engines (PACE) - A Light-Duty National Laboratory Combustion Consortium Principal Investigator: Paul Miles (Sandia National Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Kudos to the Partnership for Advanced Combustion Engines (PACE) Leadership Team on organizing such a broad spectrum of research and keeping it focused on barriers relevant to high- volume LD combustion. The presentation was well structured. The reviewer really liked the structure of the PACE presentations focusing on a PACE deliverable by a team leader rather than by National Laboratory. This clearly shows the collaborative nature of the new Partnership.

Reviewer 2:

The approach is well designed to meet objectives. It is organized into relevant categories and tasks that are measurable and that lend themselves to effective management. A key part of the approach is the utilization of DOE's world-class high-performance computing to reduce engine design cycle times.

Reviewer 3:

The PACE umbrella is focused on important topics that are relevant to industry. The collaboration between labs all working toward critical goals is an improvement compared to past projects where labs worked independently. The project addresses current barriers to accurate engine simulation.

Reviewer 4:

The approach to this project is excellent. The reviewer had long thought that a more coordinated effort among the various National Laboratories was needed, and this project addresses that. The project is very well focused on three overarching goals. The project has a well thought out work plan with important milestones and success measures documented. The reviewer believed the project is feasible, but it will be very challenging to meet all of the goals and milestones laid out. This is the only reason the reviewer gave this an “Excellent” score and not an “Outstanding” score.

Reviewer 5:
On paper, the program looks good. It is an early effort, however, so the proof will be clearer once the program has progressed forward. The reviewer commented that it is good to see “open source” sub-functions as primary simulation deliverables. Delivering a usable, open-source product to OEMs is a key target. Moving forward, it will be important to show uptake by end-users, so the reviewer suggested considering implementing technology transfer metrics into the program to track adoption of the sub-models being developed.

If the high performance computing (HPC) is being used as benchmark for simulation, it will need to be very clear on how accuracy of the HPC simulations are evaluated. These will need to be validated against experiments and, if they are being used as a reference, it will be critical to evaluate whether they are delivering results that are real.

The reviewer would have liked to see greater detail on how specifically machine learning is being applied to increase speed. Machine learning can be a trendy buzzword, so specificity on how this is improving program delivery is important. In future AMRs, the reviewer would like to see clear, concrete results on how machine learning has benefited this program.

Many of the individual projects appear to be efforts that have been in-flight for multiple years now in a different guise, and these projects need to be brought together in a very cohesive form. Also, for projects that have been in-flight for a while, why have these not been picked up by OEMs already? Are the technologies still relevant? Moving forward, there will need to be a close connection to, support from, and endorsement by engine manufacturers that technologies being developed are of interest and have the potential to be commercially viable. Especially for novel combustion programs, such as Major Outcomes 5 and 7 on Slide 14, PACE should look to “dual-use” developments, which have greater crossover with conventional gasoline and diesel applications for higher utility in case OEMs do not adopt a specific concept. Also, the project team needs to include robust, actual decisions with consequences and Go/No-Go decisions to ensure efforts are moving forward.

While recognizing that the move to a single engine platform may increase the speed to deliver modeling advancements, this reviewer was concerned that limiting to one engine design will impact the ability to deliver model validation. Improved, validated, modeling tools should be engine-agnostic and validated across a range of different engine platforms. The project team needs to be clear on how the new format—grouping all labs/programs under a common umbrella—will deliver improved performance and results to the automotive companies on such a spread array of topics. Consider focusing on fewer, but higher impact, topics, which might be a better utilization of lab resources. The reviewer would like to see key identification of barriers and connection for each program, including both a clear opportunity statement and vision of success. What are the key limitations and barriers to progressing the technology to market, and how are these being addressed?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The program is about 25% complete, which is on target given the start and end dates. With such a large program, it can be difficult to keep the goals in focus. This overview did a nice job laying out goals and milestones, and the reviewer hoped they are maintained (and completed) throughout the program.

Reviewer 2:
Even early on in the program, there have been notable collaborations. For example, the development of a new gasoline fuel surrogate demonstrated successful collaboration between multiple National Laboratories, and this hopefully indicates how well the PACE collaborative approach will work.

Reviewer 3:
Since PACE is quite young, the expectations for technical accomplishments are low. Focusing on the definition, formulation, and validation of a common surrogate fuel is a great first step. Also, it is good to see there is some effort to identify a common engine architecture.

Reviewer 4:
Developing a surrogate for gasoline has proceeded at a fast pace and results are already available. Prediction of knock has also made good progress.

Reviewer 5:
The reviewer recognized that this is a very early phase effort starting in in the fall of 2019. This specific presentation focuses on the high-level and administration effort, but the overall effort has not seen significant progress beyond planning. Accordingly, judgment of overall accomplishments and progress will likely need to be withheld until 2021. Most project milestones are phased toward the end of the year, either quarter (Q) 3 or Q4. These are generally "on track," but this is not particularly informative given the time remaining. Moving forward, the reviewer would like to see more project milestones that are more specific and represent significant progress. Shift away from readily achievable, but meaningless, process milestones toward those delivering answers to specific obstacles, barriers, or steps along the research pathway.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration and coordination in this project are outstanding. One of the main strengths of this program is the multi-National Laboratory leadership and execution. The strengths of the various National Laboratories and groups are leveraged, but toward a few common, focused goals. This helps avoid redundancy among the National Laboratories and significantly increases the chance of success of this program.

Reviewer 2:
There are six National Laboratories being coordinated effectively to collaborate with no duplication and instead complement and supplement each other. The input from the U.S. DRIVE ACEC Technical (tech) team, which represents the needs of the light-duty OEMs, has been received very well and the program has been designed to meet ACEC priorities.

Reviewer 3:
The fuel surrogate development shows great collaboration between National Laboratories.

Reviewer 4:
There is clear evidence of collaboration in this new Partnership. It is much better organized than past, somewhat isolated research efforts. The reviewer really liked the structure of the presentations. Being focused on the deliverables rather than by PI or National Laboratory provides assurances that goals will be achieved. The reviewer was glad to see the CFD vendors being part of the Partnership. With regards to cold-start emissions, the reviewer would have liked to see more information on how PACE will collaborate with aftertreatment research teams.

Reviewer 5:
There is a clear and significant focus on working together, but it is not clear how well the projects are truly linked behind the scenes. They appear to be a standalone set of projects, with primarily alignment in high-level purpose, platform, and fuels. The reviewer would like more detail on the program's external connections

beyond the U.S. DRIVE ACEC and Advanced Engine Combustion (AEC) Memorandum of Understanding (MOU). These are not well detailed and simply stated as "numerous." The reviewer would appreciate highlighting organizations and explain how these form a cohesive connection to the task and purpose of the program, and how the output of this program sees uptake by customer organizations. It may also be useful to the program for a method to solicit active review and directional input outside of AMR and ACEC review meetings. For example, the Co-Optima program has stakeholder engagement and oversight boards.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer looked forward to results of the Partnership.

Reviewer 2:
The future plans were not discussed extensively in the presentation. Questions remain as to how some of the barriers will be addressed.

Reviewer 3:
The overall goals and targets of the program are laid out well, but there is not necessarily a coherent work plan provided in this summary. Several of the thrust areas, the major outcomes, are not overly specific as to what final success looks like: for example, Major Outcomes 3-8. More clarity is necessary in these areas to define a quantifiable result state, which could be considered success. This is especially important for projects that have been in-flight for a number of years already. Lack of a defined target and focus on "improvement" is a recipe for an evergreen program.

Reviewer 4:
The use of artificial intelligence (AI) and machine learning (ML) should be handled carefully. Lots of precious time can be wasted in perfecting a ML model with little or no understanding at the end. PACE should develop sub-models to encapsulate physical understanding. Oftentimes, these sub-models can be very expensive with high run times. Machine learning should be used to handle the turnaround time and leave the physics for the sub-models.

The partnership with the software companies should be effectively managed to put all the knowledge and understanding gained from the program into the hands of OEM engine designers in a platform that they can use and afford.

Reviewer 5:
In the oral presentation, the speaker described future models coming from this program as "user ready" and "plug 'n play." The reviewer would urge the group to spend some time scoping out this part of the program. It sounds relatively easy, but in practice this can be very difficult. Also, the reviewer realized that there are many other presentations covering PACE in the merit review; however, the reviewer still would have liked to see some additional information on the codes that will be used for the direct numerical simulations (DNS). Why are these codes needed if the ultimate goal is to get the models into commercial codes used by the OEMs?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
There is a clear connection to DOE Vehicle Technologies Office's objective to improve vehicle energy efficiency and emissions. Sub-programs address an array of topics supporting technology development to understand and address topic areas relevant to increased engine efficiency. Simulation tool development can aid automotive manufacturers by enhancing their tools for developing new technologies to increase engine efficiency and improve emissions.

Reviewer 2:
The reviewer commented yes, this project supports the overall DOE objectives. One of the four R&D Focus Areas of the EERE VTO is Advanced Combustion Systems and Fuels with a 35% fuel efficiency improvement target. This project very clearly supports that mission.

Reviewer 3:
This program is highly relevant to the light-duty OEMs. Light-duty internal combustion (IC) engines will be in the market for many decades to come. Achieving emissions, efficiency, and goals for engines is a key part of reducing national CO_2 and meeting clean air goals. Distributing the effort in the three areas of knock and low speed pre-ignition (LSPI), dilute gasoline combustion, and cold-start emissions is right on the mark in meeting the highest priority areas for the light-duty OEMs.

Reviewer 4:
The work is expected to lead to improved engine simulation tools that will help manufacturers improve engine efficiency and reduce energy consumption.

Reviewer 5:
Improved understanding and computer-aided engineering (CAE) tools will directly enable OEMS to produce more efficient and cleaner ICE.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The tasks laid out for the PACE project are very daunting and it is likely that more resources will be required to meet the goals. In addition, sooner results would help industry, which also requires more resources.

Reviewer 2:
The reviewer believed that the resources are sufficient. It is a significant amount of funding; however, there is a substantial amount of work under this program. If the goals are met, it will have been well worth it.

Reviewer 3:
Resources are generally sufficient. It is critical that the efforts to provide a common engine platform (single, optical, and multi) to all the participating National Laboratories has prompt and sufficient funding.

Reviewer 4:
The reviewer commented sufficient.

Reviewer 5:
Overall funding of $9 million per year covers a wide breadth of projects. Looking at specific budgets, however, there is a wide range of project funding levels and individual sub-project splits across different PIs. There is little explanation for the disparity between funding levels, and why certain efforts require more funding, in some cases significantly more, than others. Additionally, given that projects are at varied progression, with some new efforts and others appearing to be minor variations on projects that have been running for a long time, more clarity on how effort and funding are determined would be useful.

Presentation Number: ace139
Presentation Title: Development of an Optimized Gasoline Surrogate Formulation for PACE Experiments and Simulations
Principal Investigator: Scott Wagnon (Lawrence Livermore National Laboratory)

Presenter

Scott Wagnon, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 20% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

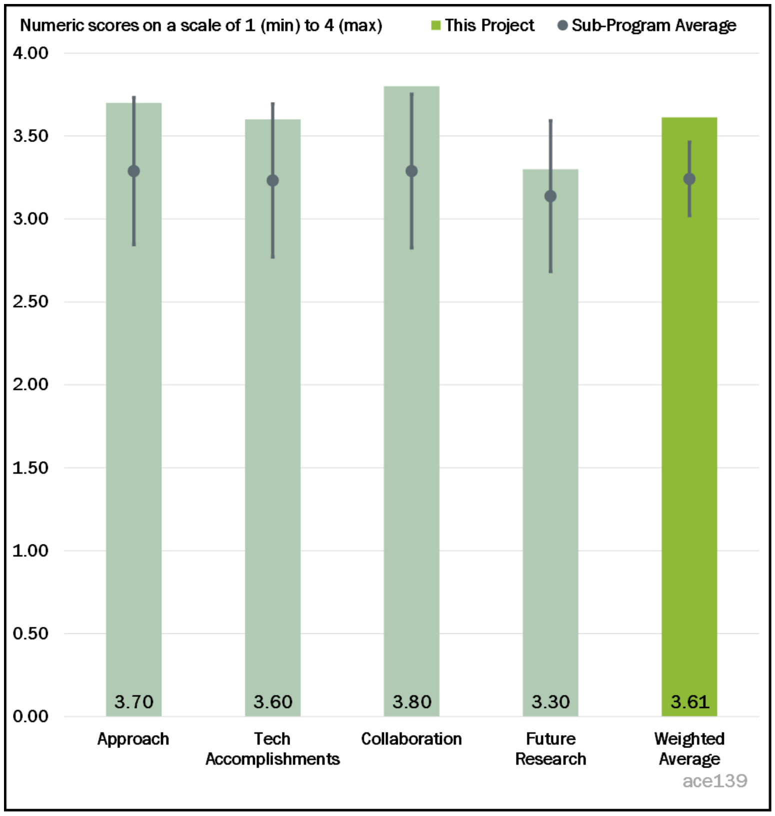

Figure 1-23 - Presentation Number: ace139 Presentation Title: Development of an Optimized Gasoline Surrogate Formulation for PACE Experiments and Simulations Principal Investigator: Scott Wagnon (Lawrence Livermore National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer called this a fantastic approach and really liked the quick organization of a surrogate working group to develop a common fuel for PACE. How does RD5-87 fuel compare to pump grade 10% ethanol content gasoline (E10)? The reviewer suggested maybe getting a fuel specification from one of the OEM research fuel suppliers.

Reviewer 2:

The multi-variable optimization approach provides a good means to generate fuel surrogates, especially if the model can run on massively parallel architectures. It appears that the optimizer adjusts the mass fractions of pre-selected species. Are there any plans in the future to allow the optimizer to choose both the species and mass fractions?

Reviewer 3:

It appears to the reviewer that this is a well-designed project to holistically develop gasoline surrogates that match knock metrics: research octane number (RON)/motor octane number (MON), particulate matter index (PMI), distillation curve, auto-ignition timing, heat release, etc. It covers mechanism development for fuel combustion and pollutant formation, validation, as well as model reduction. However, it is not very clear what the final outcome of the project is. In addition to better developed surrogates, will this project develop a tool that facilities OEMs or other researchers developing a mechanism/surrogate that matches the desired fuel properties mentioned above?

Reviewer 4:
The reviewer would suggest looking at the boosted CFR engine work of ANL's Chris Kolodziej, who has done a considerable amount of work on knock in boosted conditions with respect to fuel properties. Maybe consider having him evaluate some of the surrogates since RON and MON can be difficult to model if high percentages of aromatics or olefins or both react nonlinearly (sometimes) if they are present in the surrogate in large quantities and they are in the presence of ethanol. The knocking potential also changes differently with boost and fuel composition. To confound things more, knock and ignition delay (from a rapid compression machine [RCM]) are considerably different. An RCM is designed to take out as many physical effects as possible to measure the chemical effects of ignition delay. There are physical phenomena that are affecting the end gases in an engine that are not present in an RCM, such as the pressure wave from the flame front, heat transfer, and bulk fluid motion. This can be characterized in the CFR engine (which is designed to withstand knocking events) and may help with the correlation between the RCM and the metal engine.

Reviewer 5:
This is a solid approach to a central element bridging the experimental measurements and simulations that are a key output of the program. The use of a large sub-team to gather appropriate expertise is laudable. The optimizer appears to have been a very powerful tool to enhance the speed of the effort.

With surrogates, the key questions always are how representative a reduced set of components are to mimic operation of the target fuel. Given that, this reviewer had concerns with the assumption that tetralin can be added to match PMI and account for the high boiling range components otherwise not included in the surrogate. Tetralin can have a strong impact on particular behaviors, such as PM emissions and LSPI, and may not be fully representative of the heavy-end components. It will be important moving forward to compare tetralin against potential other components for extending the boiling range and matching PMI to understand if effects found are truly representative of matched fuel properties or if tetralin is having an overwhelming impact on results. In the presentation, it is unclear what specific projects are under this effort, as opposed to merely related works.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The team has a thorough approach of validating surrogates and kinetics with distillation, flame speed, and auto-ignition measurements. Furthermore, will the optimization tool be available as open source?

Reviewer 2:
The reviewer affirmed the project team is making great progress on matching the relevant fuel characteristics.

Reviewer 3:
The project made good progress, accomplished about 25% of this 4-year program, observed some delays but understandable due to the current pandemic situation. The team developed new measurements and kinetic models and delivered reduced kinetic model for cold-start simulations. An initial shared surrogate fuel was defined, verified, and tested in research engine tests.

Reviewer 4:
The reviewer indicated that the computational efforts in developing surrogates are unique and impressive. The reviewer did however, question the extent of the validation efforts. RON and MON are fairly complex and do not always match well with engine and RCM data. RCMs have a low-intake air charge motion in the combustion chamber and engines have different end-gas conditions, so using a CFR engine to validate RON and MON should be done. Also, RCMs are CI in nature (and attempting to measure chemical effects) and

knock occurs in forced combustion (SI) where conditions are not the same as an RCM. That being said, if there were a way to give this a 3.9 instead of a 3.5, the reviewer would.

Reviewer 5:
Overall, this is a strong first-year effort, delivering a recommended surrogate fuel and evaluating across a range of platforms to understand and validate performance against the target fuel.

Performance was documented across a range of platforms, with shortcomings of the proposed surrogate fuel identified. This reviewer did take issue with the idea that behaviors are "well validated," because that term usually implies very closely matched performance. Across the different platforms, different shortcomings were identified as were aspects where surrogate fuel and target fuel performance deviated, in some cases significantly. This does not square with the phrase "well validated."

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
It is impressive that there is cooperation across four National Laboratories.

Reviewer 2:
PACE structure is clearly showing improved collaboration versus past efforts. The reviewer really liked the goal-oriented approach (focus on deliverables).

Reviewer 3:
The team from Lawrence Livermore National Laboratory (LLNL) is engaged across National Laboratories to validate against experiments and link with CFD simulations.

Reviewer 4:
Good collaboration across a range of National Laboratories to support this effort. The cross-laboratory sub-team stood up to help develop and test a new surrogate fuel for the project. Fuel was tested across a range of different engine platforms, leveraging experimental facilities across different National Laboratories.

Reviewer 5:
The reviewer found strong collaboration with National Laboratories, along with a few universities. The PIs should strengthen collaborations with OEMs.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Generally speaking, the future research is well planned. As researchers are exploring new gasoline combustion modes, the reviewer hoped a tool can be developed and publicly shared to generate surrogates at the end of this project.

Reviewer 2:
With surrogate mixture design for the PACE effort nearing completion, there should be a declining need for a similar effort moving forward. Understanding properties and developing kinetic models for use in simulations is a prudent next step. The nature of the work in this project may lead to an activity that drives on in perpetuity. Given the need for simulation efforts and experimental work to link together, there will reach a point where development needs to be frozen to allow the other efforts, central to the PACE program, to move ahead.

Reviewer 3:
The reviewer remarked that the team should continue to pursue changes to get better soot match at high catalyst heating conditions.

Reviewer 4:
Getting an agreement between the RCM and one engine does not validate the surrogate. It is promising that the surrogate agrees with the ORNL engine and RCM data, but validation in a couple of broadly different engine platforms will show how well the surrogate performs.

Reviewer 5:
It is unclear from the presentation material if there are unique experiments that are needed to validate surrogates and mechanisms specific to each of the objectives outlined in Slide 4. Do the National Laboratories have the capability to provide relevant experimental validation measurements, especially for cold start?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This work is absolutely relevant to DOE objectives. Motor gasoline accounts for 45% of the crude consumed in the United States. Advancing gasoline engine technologies will continue to play a key role in reducing GHG emissions. Fuel surrogates and mechanisms are crucial to the success of future engine development.

Reviewer 2:
Common surrogate gasolines for all PACE work are critical.

Reviewer 3:
Developing validated surrogates and kinetic mechanisms that each of the National Laboratories can share is vital to the PACE program goals.

Reviewer 4:
This project fits the overall DOE objectives of the PACE group. This project will go a long way to enabling the modeling portion of PACE to interface with the fuel spray and combustion portion of PACE.

Reviewer 5:
The overall PACE effort supports the DOE objective to increase vehicle fuel economy and reduce emissions through development of modeling tools for automotive manufacturers. Surrogate fuels are an important link between experiments and CFD models.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The team has sufficient resources.

Reviewer 2:
Sufficient, the PI did not indicate research is hampered by lack of resources.

Reviewer 3:
The project could use testing in a CFR engine to understand how the surrogate performs under knocking conditions, allowing for a better prediction of knock. The leap from RCM to full metal engine is pretty large, and an effort should be made to compare the surrogate in several engines. Overall, this a really well-run project.

Reviewer 4:

Overall, the team has most resources to conduct the relevant research—RCM, engine, modeling tools, etc. However, additional experiments should be conducted for model validation, such as flame speed and ignition delay (ID) at higher temperature.

Reviewer 5:

There is not great clarity within the presentation on the scale of activities being funded under this effort. Funding expands moving forward though the key deliverable, a surrogate formulation, is well on its way to completion. It is not clear why the future work for the program requires the sharp increase in funding.

Presentation Number: ace140
Presentation Title: Improved Chemical Kinetics and Algorithms for More Accurate, Faster Simulations
Principal Investigator: Russell Whitesides (Lawrence Livermore National Laboratory)

Presenter

Russell Whitesides, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

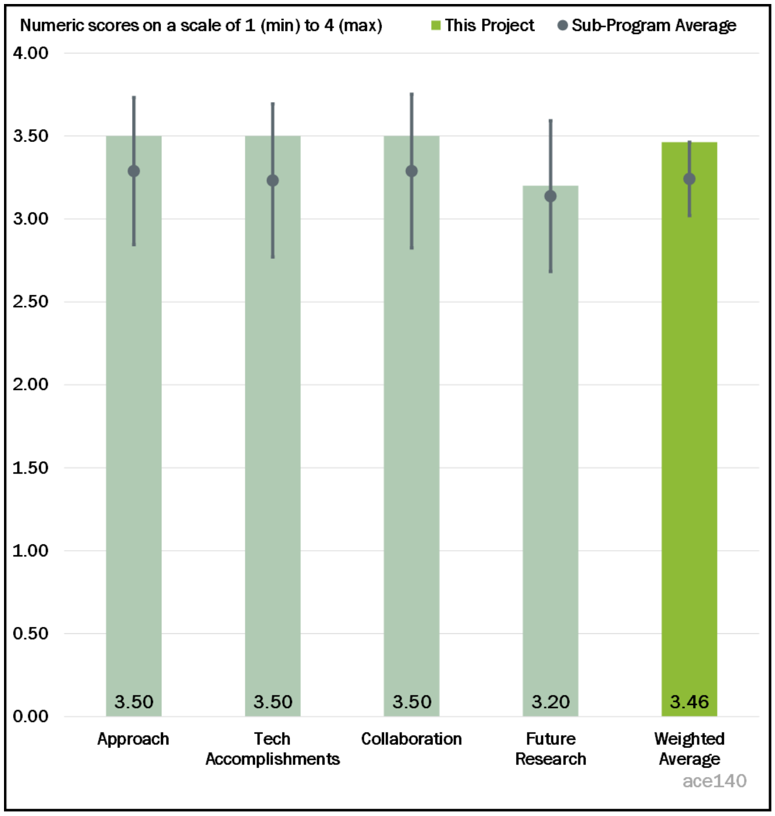

Figure 1-24 - Presentation Number: ace140 Presentation Title: Improved Chemical Kinetics and Algorithms for More Accurate, Faster Simulations Principal Investigator: Russell Whitesides (Lawrence Livermore National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Using supercomputers helps provide a benchmark against which engineering-level simulation tools can be compared, so this project is very useful. In addition, the use of supercomputers to develop faster simulations helps the speed of engineering simulations. The goals of this project are well aligned to the overall goals of the PACE umbrella.

Reviewer 2:

This presentation reviewed three separate tasks. Overall, the approach to each task is sound and well planned. A minor concern is the handling of the challenges associated with the third task (mechanism reduction). Effort is needed to generate a more coherent plan to identify other possible solutions, r to establish that a suitable mechanism reduction may not be possible. The reviewer provided further comments in the Technical Accomplishments and Progress section.

Reviewer 3:

The use of a neural network to choose the integrator on the fly is a very interesting technique. Please provide information about the integrators in Slide 7. Also, please compare the approach in this project to the Hybrid model of Professor Hai Wang at Stanford University.

Reviewer 4:
The project directly addresses a major technical barrier to enhanced-fidelity engine simulations – the computational cost of reaction kinetics in CFD codes. The use of a neural network to choose the most appropriate integrator to use at each condition is a creative solution to provide another step in computational cost reduction. The challenges in applying the zero-order reaction kinetics combustion software package (Zero-RK) to new platforms are disappointing, but hopefully will lead to new understanding that enhances the ability to deploy these routines. Automated mechanism reduction routines, targeting both kinetic performance and a range of other key properties, are another way this project can directly address technical barriers.

Reviewer 5:
Chemistry calculation is always the time-consuming part of engine simulations, so its acceleration is definitely very important. Using machine learning or smartly reducing the mechanism to a much smaller size is the appropriate approach. The reviewer agreed with the approach to explore the potential of using supercomputer for such a study. One potential concern is about the detailed chemistry. Are we at the stage of truly trusting the accuracy of it due to the many uncertainties for so many reactions?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
It appeared to the reviewer that progress is on track. The PI has shown the progress of using a neural network (NN) to accelerate the chemistry and potentially exploring chemical states.

Reviewer 2:
Significant progress has been demonstrated in multiple areas, including the neural-network integrator selector, and the automatic reduction of mechanisms. The knowledge from this progress is already driving key insights; for instance, kinetic mechanisms for high-fidelity CFD will remain sizeable (300- 1,000 species) despite reduction, in order to maintain accuracy across a range of conditions.

Reviewer 3:
The continued speed-up of simulation time is impressive and will be needed for accurate engineering simulations to be useful.

Reviewer 4:
The progress on the neural network task is excellent. A minor suggestion would be to show additional validation results for more complex fuels and geometries. Such an effort would go a long way to convince potential users of the suitability of this approach. The graphics processing unit (GPU) supercomputer transitioning is behind schedule, but for reasons outside of the control of the project team – namely, the COVID-19 pandemic and an issue with the GPU hardware. The team is pursuing alternate solutions, and thus this effort should be expected to be back on track soon.

Most concerning are the accomplishments and progress with regards to the mechanism reduction effort. As noted by the presenter, most of the errors in the reduced mechanism with regard to ignition delay occur precisely in the region that is critical for SI engines. (Could this possibly be because reactions critical for low-temperature chemistry are being removed in the reduction?) More needs to be done to resolve this problem, especially if other efforts are to use this reduced mechanism. Finally, it would be very prudent to explore and show how other critical properties such as flame speed perform in the reduced mechanism.

Reviewer 5:
Please provide some information about the RD5-87 surrogate. The collaboration with Convergent Science is very good since it will improve a software package that is available to industry. Please explain how this project will improve the CONVERGE software that is available to industry.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Overall, these three tasks are well coordinated and collaboration among the team appears to be good. The engagement with outside entities is excellent and will ensure that industry can readily benefit from this work.

Reviewer 2:
The collaborations encompassed by the project, between LLNL, ANL, and GM, will push the boundaries of high-fidelity engine CFD through reduced computational costs, which allow the use of more accurate models. Other key applications, such as mechanism reduction, will be used widely by PACE and Co-Optima.

Reviewer 3:
It is good to see collaboration that includes Convergent Science because this is key to deploying your new techniques to industry.

Reviewer 4:
The PI is working with the right teams, Convergent Science has the most popular engine CFD software, and GM brings the industry technical inputs. The team also works with other team, to implement the methodology to other DOE-sponsored codes.

Reviewer 5:
Please provide information about the role of each collaborator (e.g., ANL, Goldsborough, and rapid compression machine experiment).

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The future work was not discussed in significant detail, but overall the planned work is in the appropriate direction. It would be helpful to have had a coherent plan, including backup and risk mitigation plans for each task. This is especially relevant for the mechanism reduction effort. Some minor suggestions with regards to this are to evaluate the potential of reducing the optimization region, or to show how alternate approaches perform to establish that the proposed method is the "best possible" one.

Reviewer 2:
Thank you for focusing future work on finding solutions to Summit problems. Please state decision points. The Reinforcement learning based mechanism reduction is very interesting.

Reviewer 3:
All the future planned work is relevant and interesting. If resources allow, the team might also consider soot (polycyclic aromatic hydrocarbon [PAH]) related species into their kinetic model. Emission modeling is more demanding than ever.

Reviewer 4:
Slide 18 shows that accelerated solvers have eliminated the chemistry bottleneck in combustion CFD calculations. Can any of the project team's acceleration techniques be applied to other areas of the simulation to speed those up as well?

Reviewer 5:
Enabling additional computational cost reductions through improved handling of species transport will further address technical barriers. It would be nice to see greater plans to share and put to use the automated mechanism reduction routines, so that researchers with less experience in numerics could put this work to use.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project supports DOE's overall objectives. Most notably, it will result in a rapid deployment of improved simulation techniques to industry to help improve the efficiency and reduce the emissions of future engines.

Reviewer 2:
The reviewer remarked that it is a very important topic. The project can answer what the best chemistry methodology is in engine simulations.

Reviewer 3:
Knock prediction is relevant to industry and the DOE. Collaboration with an industrial partner (GM in this case) supports the DOE objectives.

Reviewer 4:
Improved chemistry calculation speed makes robust simulations available to engine designers working on the next generation of IC engines and should contribute to DOE's goal of reduced energy consumption.

Reviewer 5:
Fast and accurate kinetics are an enabler for high-fidelity CFD – a primary objective of the PACE project. Computational cost is high for accurate kinetics – efforts to lower this cost will enhance the regimes to which CFD can be practically applied.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This project significantly contributes to overall PACE goals of improving engine CFD fidelity and should not see a reduction in budget.

Reviewer 2:
The resources are sufficient for the various tasks to succeed.

Reviewer 3:
The resources appear to be sufficient in the sense that the scope of the future work addresses the issues.

Reviewer 4:
The reviewer stated that resources are sufficient.

Reviewer 5:
The pandemic might delay the progress, but overall resources seem reasonable.

Presentation Number: ace141
Presentation Title: Advanced Ignition System Fundamentals
Principal Investigator: Isaac Ekoto (Sandia National Laboratories)

Presenter

Isaac Ekoto, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers indicated that the resources were sufficient, 20% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

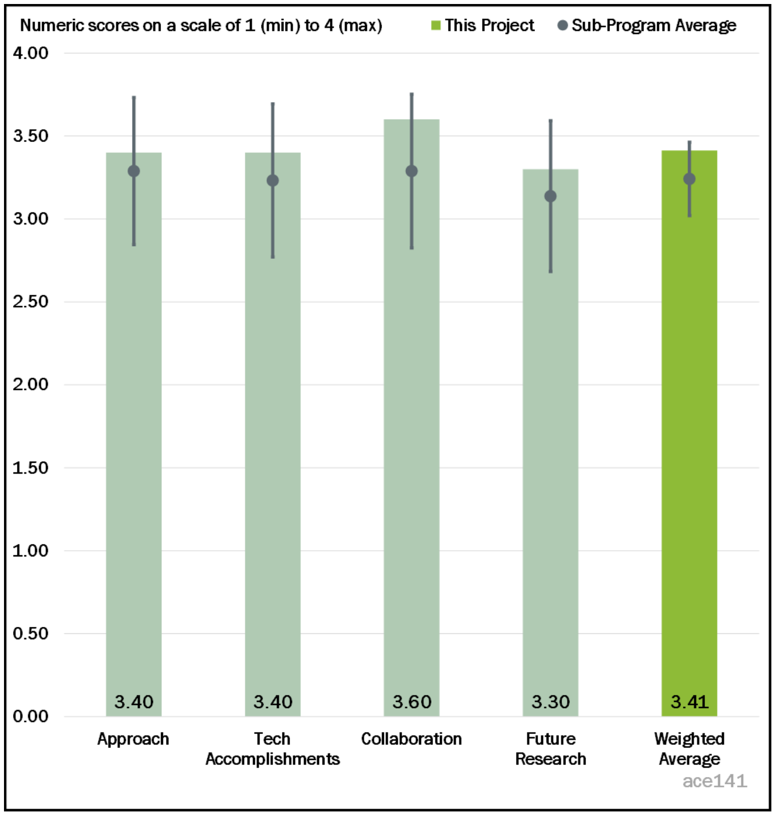

Figure 1-25 - Presentation Number: ace141 Presentation Title: Advanced Ignition System Fundamentals Principal Investigator: Isaac Ekoto (Sandia National Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The PI and collaborators are using a good approach to overcome the barriers in understanding and predicting ignition phenomena in engines.

Reviewer 2:

The approach to the project is well designed: performing detailed measurements of the phenomena occurring during ignition for different ignition systems under different conditions, then coupling this with advanced simulation approaches to maximize the progress and learning.

Reviewer 3:

The modeling effort to replicate spark and corona ignition is excellent. There are different theories on how jet ignition works. If the nozzle quenches the combustion, radicals will ignite the fuel air mixture. This is significantly different than spark or corona ignition. This effort is needed to understand the mechanisms this ignition process uses.

Reviewer 4:

The reviewer suggested continuing to pursue stoichiometric dilute combustion versus lean. Is there a point in the research where you can narrow the options to one ignitor path? Can you focus more resources on that single path (i.e., go deep on one idea or try to touch on multiple different methods but do not go so deep)?

Reviewer 5:
The project tends to go very deep into the physics. While this work is very impressive, more basic measurements of the ignition energy, both primary and secondary, should be made and reported.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer affirmed the technical accomplishments are excellent.

Reviewer 2:
The modeling of the spark and corona ignition was excellent, and the design and development of the cross-flow ignition test facility that reproduces relevant in-cylinder densities (30 gram [g]/L) and velocities (30 meters/second [m/s]) are impressive.

Reviewer 3:
The reviewer was impressed by project outcomes when considering the limited funding it relies on.

Reviewer 4:
The reviewer found great progress, considering that the project started in Q3 of 2019.

Reviewer 5:
So far, results that can be used by industry in extending the EGR tolerance of stoichiometric gasoline combustion have not been met.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration is excellent. The reviewer was pleased that USCAR was engaged in accessing research priorities.

Reviewer 2:
There was excellent collaboration between experimentalists and modelers.

Reviewer 3:
The extent of collaboration and coordination across the team is very good and supported by results despite the current (difficult) environment.

Reviewer 4:
The new PACE structure clearly improves collaboration and allows focus on barriers.

Reviewer 5:
The reviewer commented that perhaps more collaboration with conventional ignition system suppliers is required to keep the project at a practical level.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future work is in line with project goals and milestones.

Reviewer 2:
The question raised regarding comparing the results between these new ignition systems and current ignition systems with equal energy input raised an important point. In the reviewer's opinion, this should be integrated into future plans.

Also, the reviewer thought that an emphasis on EGR tolerance at stoichiometric conditions should also take a more prominent role in future work. Pursuing ultra-lean combustion has the potential for yielding higher efficiency so it is important. However, the reviewer's impression is that industry is not eager to pursue lean burn systems because of the increased cost of the aftertreatment systems, especially in light of the investments they are making relative to electrification. In the near term, the reviewer guessed that industry will be more interested in extending EGR tolerance at stoichiometric conditions than pushing lean limits.

Reviewer 3:
The reviewer was looking forward to active pre-chamber research. Are catalyst heating conditions sufficiently represented in the future plans?

Reviewer 4:
Predictive ignition modeling serves multiple purposes in PACE by allowing for prioritization needed, depending on the current state of the art and the available test time. Pre-chamber (PC) or low-temperature plasma (LTP) igniters are likely to remain at the engineering level in the next several years. High turbulence, pressures/temperatures, and convective flows are challenging to mimic in combustion vessels and should be explored. How do we leverage current understanding for electrode wear?

Reviewer 5:
The focus should be significantly more on extending EGR tolerance than on lean limit extension. Also, investigations on advanced compression ignition (ACI) combustion modes should be included in Co-Optima reports and not on PACE reviews. More work on pre-chamber ignition and high-load ignition should be conducted as these are important to the OEMs.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The high-energy ignition systems look to be an enabling technology for advanced SI and mixed-mode engines. This will be important to DOE's mission as ICEs will be part of the vehicle mix for decades to come.

Reviewer 2:
Advanced igniters and understanding the ignition source contribution to cyclic variability will improve both dilute combustion and catalyst heating mode operation.

Reviewer 3:
Understanding and controlling ignition is a prerequisite for better efficiency and emissions in advanced combustion strategies.

Reviewer 4:
The close coordination between PACE and U.S. DRIVE and USCAR makes DOE relevance essentially by default.

Reviewer 5:
While the project is highly relevant to DOE and OEM objectives, the approach and focus can be modified to have more impact.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources look to be sufficient for the research being conducted.

Reviewer 2:
Funding should support post-doctoral staff to help accelerate and possibly improve the project outcomes.

Reviewer 3:
The reviewer commented sufficient. The PI did not indicate additional resources would improve the outcome.

Reviewer 4:
There was no indication that funding was insufficient.

Reviewer 5:
Resources are sufficient but need to be channeled to higher probability of impact areas as mentioned above.

Presentation Number: ace142
Presentation Title: Development and Validation of Simulation Tools for Advanced Ignition Systems
Principal Investigator: Riccardo Scarcelli (Argonne National Laboratory)

Presenter

Riccardo Scarcelli, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers indicated that the resources were sufficient, 25% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

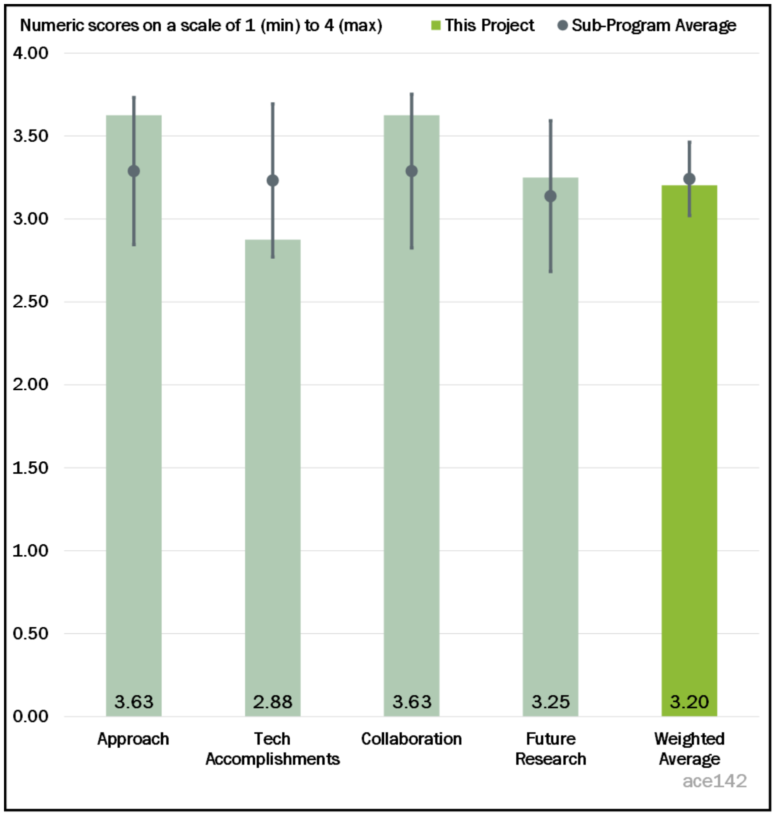

Figure 1-26 - Presentation Number: ace142 Presentation Title: Development and Validation of Simulation Tools for Advanced Ignition Systems Principal Investigator: Riccardo Scarcelli (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The presentation nicely outlines current challenges with the predictive ignition model. It presents how the current project is working toward overcoming the barriers.

Reviewer 2:

The hybrid experimental-numerical approach to providing insight into ignition system processes, which can be leveraged to create sub-models for CFD, is well founded and addresses a notable technical barrier to CFD applications for SI engines.

Reviewer 3:

This work is developing and adapting models for advanced ignition systems, addressing key technical barriers that could result in improved ignition systems for internal combustion engines. Overall, it is very well designed and planned. The investigators clearly have a very good understanding of all processes involved in advanced ignition.

A minor concern from this reviewer is that cyclic variability and its potential impact on the modeling and assessment of these advanced ignition systems is not at all included in the work plan. Given the extent to which cyclic variability and stochastic processes can impact early flame kernel growth, in the opinion of this reviewer it would be prudent to include variability in the initial and boundary conditions somehow in the work plan, or somehow otherwise look at cyclic variability.

Reviewer 4:
Is there an effort to quantify stochastic inputs for the models (e.g., voltage, current)?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The progress is slightly delayed, and the exact reasons for the delay were not made clear. Nonetheless, the accomplishments to date are impressive.

Reviewer 2:
The team showed several validation examples with fundamental measurements. For the machine learning analysis, how many DNS simulations were run to generate the results? How are these results going to improve the discrepancy in lean burn, flame kernel development shown in Slide 11? Does the team believe the ignition models already have enough fidelity to cover high load and cold start? It would be clearer if the team links the validation work shown in Slides 8-16 back to the specific PACE outcomes on Slide 4.

Reviewer 3:
The accomplishments are nicely summarized, although it is unclear if the project relies on existing software tools—VizGlow and VizSpark—or if the focus is rather on model implementation using currently available commercial CFD software like CONVERGE.

Reviewer 4:
The demonstrated progress in advancing spark ignition models (C.02.04) highlights the important work being done under this program and would receive a rank of “Excellent” if ranked alone. Why are the Sandia DNS simulations (C.02.01) performed using Jet A rather than a gasoline surrogate? Further, why are the accomplishments shown here based on aircraft-engine applications, rather than automotive engine applications? The Sandia DNS results do not seem aligned with the rest of the PACE program, its automotive focus, and its standardized use of RD5-87 gasoline. This task would receive a ranking of “Fair” if ranked alone.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The ANL collaboration with the University of Perugia and Tenneco is a great example of working with partners to make advances in areas of new technologies such as plasma ignitors. Collaborations between the Sandia National Laboratories (SNL) DNS work and the NREL ML work represent an effective transfer of knowledge between National Laboratory partners. Collaborations between Ekoto’s experimental work and Scarcelli’s modeling work have consistently yielded insights into the fundamental processes underlying advanced ignition systems, as well as practical constraints of these systems and influences of key parameters, such as system geometry, gas composition, and electro-dynamics.

Reviewer 2:
The team has shown collaboration with industry, academia, and other National Laboratories. The team is also leveraging other DOE programs to advance results.

Reviewer 3:
This work is well connected and coordinated with other experimental and modeling efforts within PACE, as well as with external collaborators.

Reviewer 4:
It looks like the project is well organized to leverage experimental data and simulation capabilities (DNS and large eddy simulation [LES]).

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The focus of C.02.04 on modeling of sparks rather than LTP is a prudent choice. The initial lean/dilute focus is also a good choice that will have the most immediate impact.

Reviewer 2:
While the proposed future work is appropriate and well planned, it would be beneficial to outline a plan for how this work can ultimately get to the point that industry could use or benefit from it and communicate this clearly.

Reviewer 3:
Why are cold-start and high-load targeted as later priorities over lean/dilute combustion? Adjusting these priorities would lead to more benefit to industry in the near term.

Reviewer 4:
While the proposed future work looks reasonable, it is not very clear how the "engineering level" CFD models are planned to be developed with any enhancement from the current.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This work is fully aligned with DOE's objectives and is addressing key challenges and barriers.

Reviewer 2:
The project certainly supports the DOE objectives to develop technologies for high-efficiency engines. It is true that the community lacks advanced ignition models to capture and predict those advanced ignition systems.

Reviewer 3:
Advanced ignition systems represent a key area of uncertainty in the design and simulation of advanced lean/dilute combustion systems, and therefore tasks supporting development of engineering-level predictive models advance DOE goals of improving energy efficiency in transportation.

Reviewer 4:
What is the plan to disseminate the sub-models to industry?

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented the team is sufficiently funded.

Reviewer 2:
This reviewer noted that the scope of the effort appears to have been trimmed to match the available resources.

Reviewer 3:
It appears like the resource are sufficient. The PI stated that the future work is subject to change, based on funding levels. It would be the best for the PI to lay out options to convince the reviewers for additional funding.

Reviewer 4:

C.02.04 is under-resourced relative to its foundational role in accurately modeling spark-ignition engines (in which the ignition process plays a huge role in determining operability, performance, and cycle-to-cycle variations).

Presentation Number: ace143
Presentation Title: Fuel Injection and Spray Research
Principal Investigator: Chris Powell (Argonne National Laboratory)

Presenter

Chris Powell, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers indicated that the resources were sufficient, 25% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

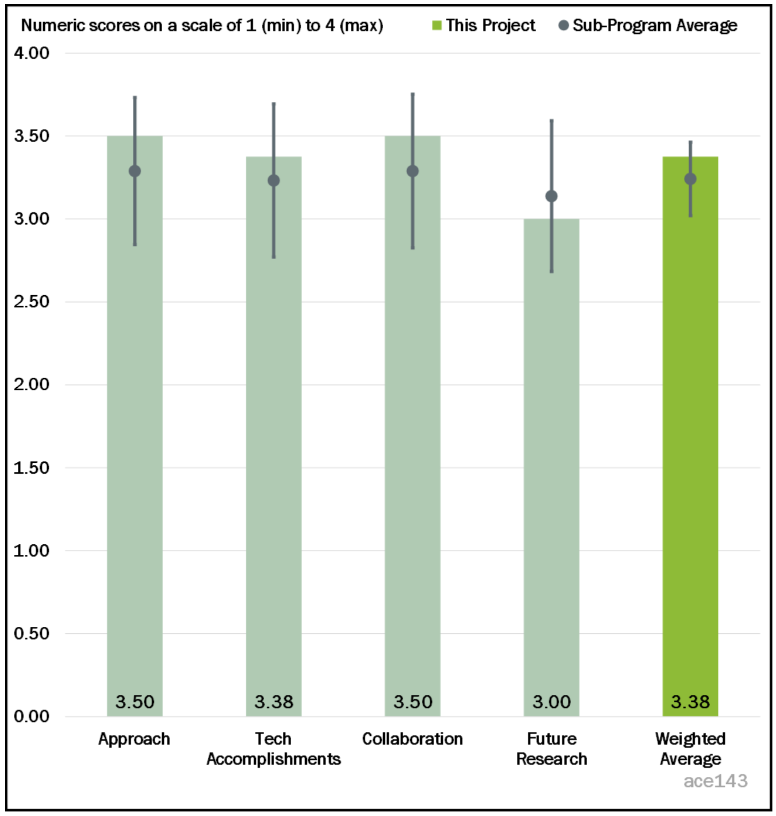

Figure 1-27 - Presentation Number: ace143 Presentation Title: Fuel Injection and Spray Research Principal Investigator: Chris Powell (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The proposed approach is solid and will contribute in addressing some of the key technical barriers. Even though success is not guaranteed due to technical challenges, the approach maximizes the probability of overcoming technical barriers by leveraging the expertise and strengths of the different National Laboratories in the PACE consortium.

Reviewer 2:

The approach is in line with project objectives.

Reviewer 3:

This multi-pronged project approaches issues surrounding sprays in a systematic and thorough way. In particular, the experimental work complements the simulation work. The experimental work uses a range of useful diagnostics to probe different physical processes during a spray at a range of relevant conditions.

Reviewer 4:

The experimental and computational coordination between SNL, ANL, ORNL, and Los Alamos National Laboratory (LANL) seems very good and appears to have a well-established foundation from the Engine Combustion Network (ECN). Using all of the labs' unique capabilities seems to be a robust approach to tackle the technical barriers, and it also seems to help upgrade or improve the existing capabilities. The project being broken into six or so tasks will clearly make project progress clearer and more manageable. It is a bit uncertain or unclear how strongly all of these separate tasks are being integrated toward the PACE goals, but maybe this is being done at a higher PACE level. The PACE program origin/structure/purpose is not fully clear to those who may not be a light-duty OEM or those who did not see ACE138.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
According to the reviewer, there are very nice results on so many topics of interest for the DOE program.

Reviewer 2:
The project is largely on track and many key milestones have already been met. There is obvious connectivity between the different partners in the task and a significant amount of comparison between different types of data, which is important. The PIs have identified important future work and remaining questions and seem on track to meet their goals.

Reviewer 3:
Even though some required housekeeping activities like the baselining of current diesel and gasoline injection models have to be completed first, the developed spray-wall interaction model is the main progress that has been reported so far. This is good progress. However, the operating conditions that have been selected to demonstrate the spray-wall interaction model fidelity for gasoline direct injection (GDI) applications are limited.

Reviewer 4:
The broad range of technical accomplishments looks to be quite good, both experimentally and computationally, as indicated by the publications and presentations. The transfer of physics understanding into computational codes and simulation methodologies looks to be starting or moving on well. The comparison of spray parameters between National Laboratories and codes and experiments was a good indicator of this movement. There is clearly a lot of work yet to be done. It is clear that CONVERGE CFD code is relevant toward the application of the knowledge learned in this project. It is not clear that the LANL simulation effort will be useful, due to the lack of commercial adoption by engine and fuel systems OEMs.

It is interesting that much of the technical discussion surrounded spray behavior with the ECN Spray G injector, but there is a clear lack of fuel system design and manufacturing expertise in the project. If the goal of this spray effort is to understand the fundamentals of sprays, fuel injection, and the predictive modeling of such, there should be a strong link to the fuel injector design. The reality may be that new spray physics understanding is generated, but there is nothing that can be changed or modified in the technology design to make improvements based on this new physics understanding. The reviewer would propose that the team try to clearly articulate how the spray physics understanding being pursued could be mapped back to the technology and design requirements. This may help focus where to really apply the R&D effort.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration between the National Laboratories, Engine Combustion Network, and industry partners is fantastic. Please keep up this good collaborative posture!

Reviewer 2:
There are excellent collaborations between the various National Laboratories.

Reviewer 3:
There is significant coordination between the different members of the project team. Each experimental measurement is complemented by others, and the presentation made clear that the physical understanding on the project is coming from the combined knowledge gained from these measurements. Further, there is a lot of

simulation that complements the experimental work, which is very helpful, and comparisons are done thoroughly.

The only area where the PIs should consider a more nuanced comparison is the issue of cycle-to-cycle variation (an overall goal of the PACE initiative), which manifests in this project as shot-to-shot variation. Capturing this well (and without enormous computational cost) in simulation is difficult but can be done—methods have been proposed to look at variance and rare events in simulation and should be incorporated into this work for better comparison to experiment. It cannot just be about comparing root mean square (RMS) levels but really getting to the root of the variance.

Reviewer 4:
It was very clear that there is a concerted effort to communicate broad National Laboratory coordination on this spray effort by the documentation in Slides 6 and 7. Maybe it would be useful to show how other collaboration is being brought into these spray efforts through the ECN, AEC, and other related collaborations. Again, there is no direct input from fuel system entities.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
There was not a large amount of future research project planning or critical decision points outlined in the presentation. However, this is more fundamental research work, and the collection of experts working on the tasks give the reviewer confidence regarding the proposed future research direction. This seems to be all in context of alignment with the overall PACE goals.

Reviewer 2:
The future work plan looks robust and covers topics of great interest to the community. There are two things that should be considered in moving forward. First, several of the future tasks have to do with multi-component fuels (measurements, preferential vaporization, etc.), and these should be done in close collaboration with the efforts in PACE that are working to develop surrogates. Additionally, these efforts should effect careful thought about how to compare these results to simulations and how the chemistry and physical properties are being modeled in the surrogates. This is an extremely important topic but one that is very hard to capture fully. Second and referencing prior comments, the reviewer commented that the issue of cycle-to-cycle variation should also be addressed in simulation as it is being researched in experiments.

Reviewer 3:
The reviewer was concerned that the experiments are testing relatively old hardware. The reviewer understood there is a task to re-evaluate this next year, but it will be helpful to have a solid plan for upgrading the experimental hardware.

Reviewer 4:
It was not very clear to the reviewer how the differences between results obtained at different labs are implemented in future work.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The work aligns very closely with the overall objectives of the PACE program and direct links between the overarching goals of the program and the subtasks here can be easily drawn. Coordination between this task and other similar tasks looks good as well.

Reviewer 2:
Yes, this foundational project on fuel injection and spray research supports the overall DOE objectives because it is a critical enabler for fuel-efficient, clean, and cost-effective internal combustion engines.

Reviewer 3:
Yes, this clearly supports energy efficiency improvements and energy security with the linkage and alignment to the PACE program. All of this work obviously focuses on automotive gasoline, which is clearly a large portion of the energy consumption in the United States.

Reviewer 4:
It is impossible to improve IC engines without better research on fuel injections and sprays.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources, both personnel and financial, seem sufficient. In particular, unique experimental capabilities are being used very well in this project.

Reviewer 2:
About half of the milestones in the project have been completed and most of the others are on track. This indicates that the milestones have been appropriately set to the level of resources assigned to the project. In addition, the physical resources and experts are working and already in place to effectively and timely complete the stated milestones.

Reviewer 3:
The funding should support more post-doctoral staff and collaborations with academia to help accelerate and possibly improve the project outcomes.

Reviewer 4:
The resources for this project should be looked at if that is the reason for the testing with relatively old hardware.

Presentation Number: ace144
Presentation Title: Spray Wall Interactions and Soot Formation
Principal Investigator: Lyle Pickett (Sandia National Laboratories)

Presenter

Lyle Pickett, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

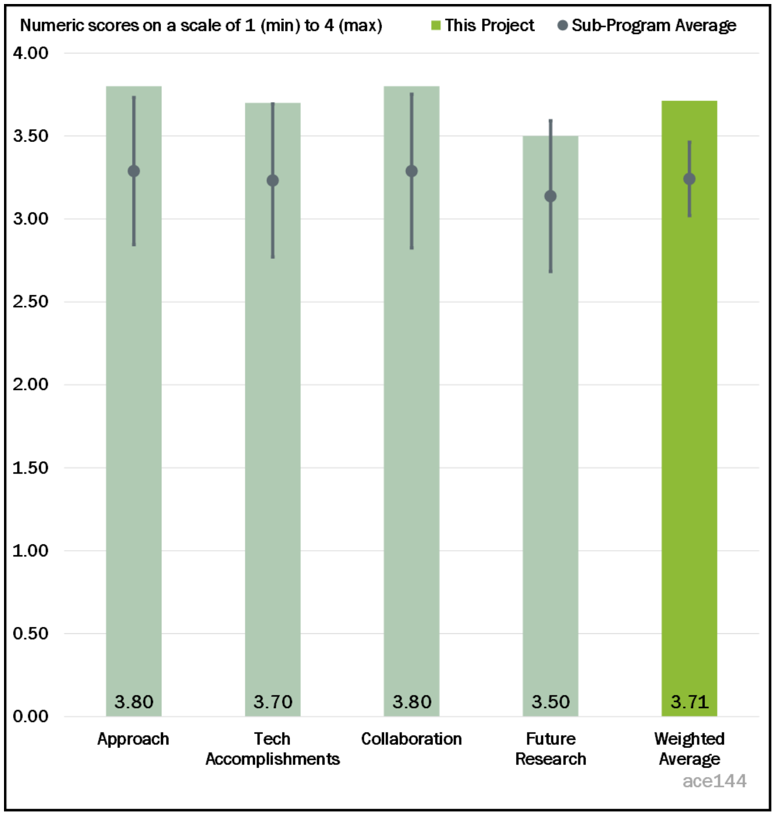

Figure 1-28 - Presentation Number: ace144 Presentation Title: Spray Wall Interactions and Soot Formation Principal Investigator: Lyle Picket (Sandia National Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach has covered the scope of the work needed to understand spray-wall interactions extremely well. The key aspects of spray impingement on the walls and subsequent soot formation and the key variables that affect them are all being addressed very well.

Reviewer 2:

The approach appears to be comprehensive, involving both experimental and simulation efforts at multiple National Laboratories. Each of the barriers from the roadmap appear to be addressed by this project: studying the mechanisms of fuel films and the physics of how they are deposited and removed. The link to knock/pre-ignition appears to be a little less clear. But, the other barriers are all directly addressed.

Reviewer 3:

The approach is excellent as indicated by the content in Slides 6, 7, and 8. It is clear this is very thought out and each major task has an approach that seems to be reasonable for its experimental or computational focus. It would be helpful to articulate how the approach will feed back and iterate with the PACE goals as knowledge and milestones are completed or missed. If there is something learned that changes the PACE assumptions and goals, how does that impact the approach?

Reviewer 4:

Many experimental techniques (X-ray, neutron) are used, which is outstanding. How does this compare with the work done by Professor Lee at Michigan Technological University?

Reviewer 5:
The approach utilizes a mixture of experimental and simulation spray diagnostics. The utilization of vertical and horizontal impinging walls provides excellent insight for model development.

The disparity in fuel rebound between experiments and simulation is large. The initialized approach where the Lagrangian switches to a volume of fluid during impingement must have vaporization added for accuracy. This was mentioned by the project team. However, the surface-temperature question during the live discussion comes into play with this first principle model development as well. The vaporization model should be developed for both cold and hot walls.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The progress on the experimental and simulation side is quite good! The project shows progress in multiple aspects of both measurement and simulation. There are fired and unfired engine conditions, benchtop and pressure vessel type experiments, and different types of simulations to attempt a predictive approach to understanding these conditions. The work was very comprehensive in using multiple tools to understand fuel/wall interactions. The link to knock/pre-ignition and the link to dilute combustion were not explicitly made in this report, and no accomplishments were shown toward these tasks.

Reviewer 2:
Excellent progress is being made in understanding a very complex phenomenon. The physics has been broken down into relevant categories to probe more deeply into the physical phenomena to make more measurements to better understand them. The shortcomings of the CFD models, like the over-prediction of the rebound, are being identified and provide areas where the models have to be improved. The effect of engine speed showing the stronger in-cylinder flows on spray collapse is very interesting.

Reviewer 3:
The project is very multifaceted and is making acceptable progress. Experiments that can distinguish between soot development modes as the flame progresses over the surface would be extremely helpful.

Reviewer 4:
Slides 7 and 8 show that the many tasks are complete. The reviewer also commented that the others are on track.

Reviewer 5:
There is a tremendous amount of technical progress and accomplishments as indicated by the eight completed milestones. The volume of presentations and publications is also high and as many as the completed milestones. The reviewer understood the fundamental nature of supplying gasoline spray wall film and soot physics knowledge and validation data, which these technical accomplishments make progress toward. There was some good discussion in the presentation on how to use the gained technical information in the predictive simulation tools. Is the goal here to help make simulation tools be as accurate as possible, or give representative key physics behavior for engineering decision making? It is not clear why there is an effort with the FEARCE code, as this is likely not a tool/code that will be adopted by industry.

Is the pursuit of wall film and gasoline soot minimization purely a cost effort? It may be helpful to clearly detail the link to the more expensive technologies required to deal with gasoline engine soot and/or cold start (e.g., particulate filters and electrically heated catalysts).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The team and the collaboration among team members was truly impressive. This team integrates very diverse experimental and simulation work across several different National Laboratories. The coordination effort was quite noticeable.

Reviewer 2:
Collaboration with the other free spray experiments at Sandia as well as experiments and modeling at Argonne are excellent. This area of work is being coordinated very well, and the leader of this subset of work is to be congratulated.

Reviewer 3:
This would be one of the benchmarks for complex project collaboration as evidenced by the strong ECN and National Laboratory coordination.

Reviewer 4:
Slides 4 and 5 show how well the teams work together.

Reviewer 5:
The multiple investigators are working on complementary experiments and models. Results appear to be well communicated between the investigators.

It has reached the point where reviewing the large collaborative efforts is nearly impossible. Teams are spending much of their time overviewing the various responsibilities and collaboration between members. There are usually only a couple minutes discussing the technical content and singular slides representing the congruous contributions from all other portions of the project. It almost seems that the reviewer would need to review all the presentations from all the collaborators to fully understand how well the projects are addressing the full scope. It is very difficult to ask questions on the technical attributes with a menagerie of content from all the collaborators.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The listing of the detailed future work is really excellent on Slides 27 and 28. The reviewer saw no issues with the future work as there has been significant milestone accomplishment and presentation and publication history.

Reviewer 2:
The critical influence of wall temperature on soot formation has been incorporated into future research. Going forward, the multi-component nature of gasoline on soot formation will be critical and this is planned. The influence of ambient air temperature and wall temperature should be studied independently as well as in unison.

Reviewer 3:
Proposed future work certainly addresses the challenges and issues that were encountered during the conducting of this work by the various team members. However, no explicitly listed future work outlines how this fundamental study of wall films will link to engine measurements of knock or dilute combustion. Those two barriers are important to include in this project, sooner versus later.

Reviewer 4:
It is a worthwhile endeavor to upgrade the experimental facilities for conditions that are closer to that of an engine.

Reviewer 5:
Evaluating spray impingement and soot formation with both high- and low-temperature walls will provide a better identification and validation if data sets for the first principle evaporation models being constructed. Careful manipulation of the wall temperature may also aid separation of the multiple soot formation pathways.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is extremely relevant and addresses probably the number one priority for OEMs, i.e., cold-start emissions and particulate matter emissions.

Reviewer 2:
The comparisons between simulated and experimental data are shown very clearly (example: Slide 19).

Reviewer 3:
GDI SI engines will be part of the light-duty automotive fleet for several years to come. To reach the efficiency and emissions compliance potential of this technology, understanding cold-start emissions and the effect of wall-wetting on knock and dilute combustion will be very important toward helping OEMs enhance GDI technologies.

Reviewer 4:
Developing fundamental insights on fuel impingement and soot formation can eventually lead to lower vehicle emissions, which is well aligned with DOE objectives.

Reviewer 5:
Yes, this project is relevant to the DOE objectives of clean and secure energy in the transportation sector. This is only aligned to automotive applications or light commercial applications.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The provided resources are being extremely well utilized in focusing on the critical and high impact issues.

Reviewer 2:
The resources appear to be sufficient to achieve the future work.

Reviewer 3:
The resources appear to be well suited to studying a problem of this size and importance. There are several National Laboratories that utilize different tools and equipment to mesh together important results. Current resources need to continue to be applied to this important work.

Reviewer 4:
The teams appear to have the support they need to modify and design the experimental devices and models required for this investigation.

Reviewer 5:
Generally, the budget seems sufficient for the tasks outlined. The tasks are rather fundamental and open ended, so it is not clear which tasks may need more resources than the others. The reviewer assumed that PACE has the ability to move budget and resource effort on a semi-regular basis to help with this. The only outlier task

looks to be the FEARCE D.02.04 effort as it seems high for the value and the lack of understanding of the use and application of the code.

Presentation Number: ace145
Presentation Title: More Accurate Modeling of Heat Transfer in Internal Combustion Engines
Principal Investigator: K. Dean Edwards (Oak Ridge National Laboratory)

Presenter

K. Dean Edwards, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers indicated that the resources were sufficient, 20% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

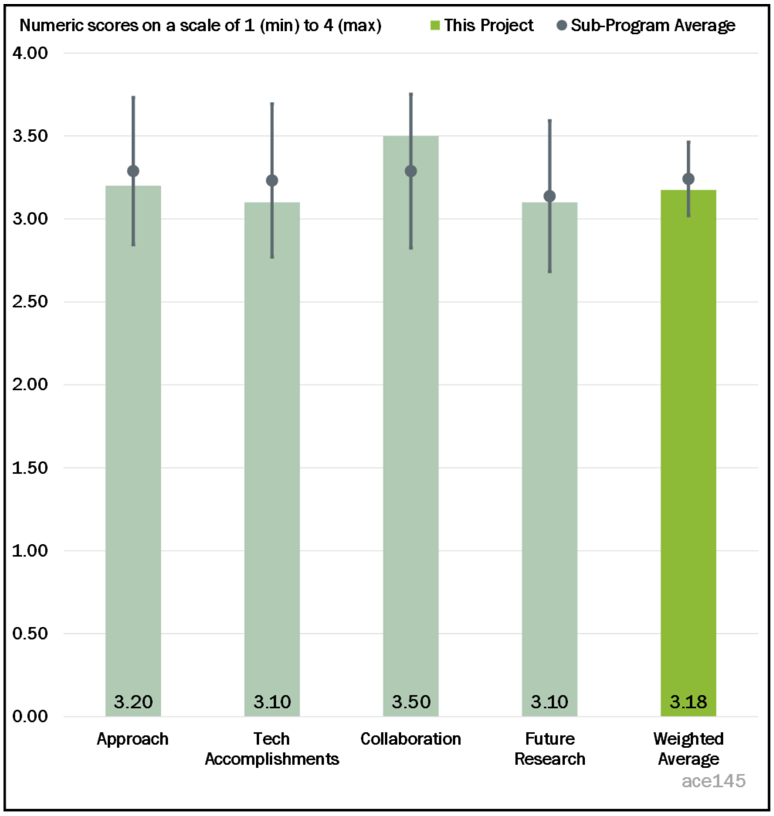

Figure 1-29 - Presentation Number: ace145 Presentation Title: More Accurate Modeling of Heat Transfer in Internal Combustion Engines Principal Investigator: K. Dean Edwards (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
It looks like this project will leverage outcomes of other projects and come up with an incorporated simulation tool (or approach). It is understood that this is rather a demonstration project.

Reviewer 2:
The team has used and leveraged the possible resources; the challenging part will be the integration of all the pieces.

Reviewer 3:
The approach to performing this work is reasonable. Predicting cold-start using CFD simulations is a tremendous challenge since it depends on a lot of uncertainty factors including heat transfer, low-temperature chemistry, spray model predictions of liquid length penetration and vapor length penetration. The work on conjugate heat transfer (CHT) and comparisons with experimental neutron diffraction data are pretty impressive. Additionally, the spray wall impingement work is also critical.

Reviewer 4:
There is a good combination of simulation and experimental work. Linking to the spray work is critical, and the reviewer was glad to see it. The neutronic engine approach is wild. Capturing a dynamometer and engine in a framework for the measurements is certainly novel. The reviewer did have questions about how the data are acquired. How much can be acquired? Is it an ensemble averaging process in both x, y, z, and time? How many unique conditions can be measured considering the complexity?

Reviewer 5:
The project goals are well aligned with PACE, but it is unclear how the project approach will deliver results in a challenging topic area.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Overall, good progress has been achieved in all three areas: i.e., computational modeling, spray imaging, and neutron diffraction in situ measurements.

Reviewer 2:
The reviewer was looking forward to the experimental neutron imaging data to calibrate and validate the CHT modeling. The collaborative link to the fuel spray work is also critical. There are interesting data showing the sensitivity of wall temperature to soot formation.

Reviewer 3:
The reviewer found the experimental setup to characterize the thermal barrier coating (BC) for modeling evaluation to be very unique. The wall-film measurement will be key for an appropriate sub -development.

Reviewer 4:
The modeling accomplishments (B.02.01) shown here have illustrated a number of stumbling blocks faced by common CFD approaches but have not demonstrated progress in overcoming these challenges. The neutronic engine work (B.01.01) potentially offers new, sought-after measurements of temperature distribution throughout the engine structure. However, it may be challenging to reach the potential of the diagnostic techniques during the PACE project duration. The choice to subcontract the engine to SwRI will likely support the rapid timeline desired for this task. The presented fuel wall-film measurement results (D.01.04/5) have a clear link to understanding soot formation processes but have not yet shed light on heat-transfer phenomena.

Reviewer 5:
The accomplishment presented is okay. However, it looks like rather a typical engineering-level exercise. The PI needs to better specify the original breakthrough.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This is an excellent example of collaboration between various different National Laboratories, GM, and Convergent Science.

Reviewer 2:
The project incorporates neutron diffraction measurements for the engine and leverages spray measurements in a constant volume chamber. Essentially, coordination and keeping collaboration and communication would be the key to the success to the project. It looks like the project is keeping it at the right level.

Reviewer 3:
The PACE structure appears to be promoting good collaboration across National Laboratories. The reviewer was glad to see involvement with software vendors.

Reviewer 4:
The reviewer said that the team has very good collaboration with various expertise included. Again, the challenge will be integration of all the pieces to work together.

Reviewer 5:
A large number of external collaborations are highlighted across the tasks and PIs. The tasks seem well linked, although only a small number of examples of inter-project coordination are given.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future work falls in line with existing task direction and is a logical extension of the results presented here.

Reviewer 2:
In the soot formation work, the reviewer suggested also considering higher speed and load conditions typical of the 20-30 second period of the Federal Test Procedure 75 (FTP-75) cycle. Fueling increases and metal temperatures can still be cold.

Reviewer 3:
The future work is comprehensive. In the reviewer's opinion, one important element is missing, i.e., kinetic model or combustion model. When approaching cold conditions (less reactive), challenges on combustion and kinetics become critical and might affect the evaluation.

Reviewer 4:
Proposed research looks reasonable. It is not clear what sub-models are to be integrated into CONVERGE for model improvement.

Reviewer 5:
The reviewer asked the team to take a step back to understand where the discrepancies in modeling are arising from. Is it from spray/vapor penetration and spreading, chemistry, heat transfer models (e.g., Woschni type model)? To understand this, every aspect of the model should be introspected and compared with fundamental experiments with cold walls. The reviewer believed that low-temperature chemistry may play a big role, and the chemistry mechanism needs to be tuned for it. In addition, how many engine cycles are needed to be simulated is a question.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is well aligned with the DOE objectives to develop a way for more fuel efficient and cleaner engines.

Reviewer 2:
PACE goals are aligned with LD ICE needs.

Reviewer 3:
Cold-start related investigation is of high interest to the community.

Reviewer 4:
Yes, the project supports overall DOE VTO objectives. These are the kind of fundamental understanding experiments and simulations that National Laboratories should pursue.

Reviewer 5:
Improved modeling of near-wall phenomena is critical for improving engine simulations targeted at limiting cases, such as cold-start or high-load. The tasks here are foundational to improving understanding of near-wall phenomena.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
It looks like the project has sufficient funding.

Reviewer 2:
The reviewer commented sufficient; the PI did not indicate additional resources would improve the outcome.

Reviewer 3:
The reviewer commented the project is on track.

Reviewer 4:
If additional neutronic engine experiments need to be performed, then the budget may be a little insufficient. Otherwise, the budget seems to be reasonable.

Reviewer 5:
The ORNL modeling task (B.02.01) and SNL experimental tasks (D.01.04/5) are resourced appropriately, but the ORNL neutronic engine task (B.01.01) is under-resourced if this task is expected to deliver results under the PACE timeline.

Presentation Number: ace146
Presentation Title: Direct Numerical Simulation (DNS) and High-Fidelity Large-Eddy Simulation (LES) for Improved Prediction of In-Cylinder Flow and Combustion Processes
Principal Investigator: Muhsin Ameen (Argonne National Laboratory)

Presenter

Muhsin Ameen, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 60% of reviewers indicated that the resources were sufficient, 40% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

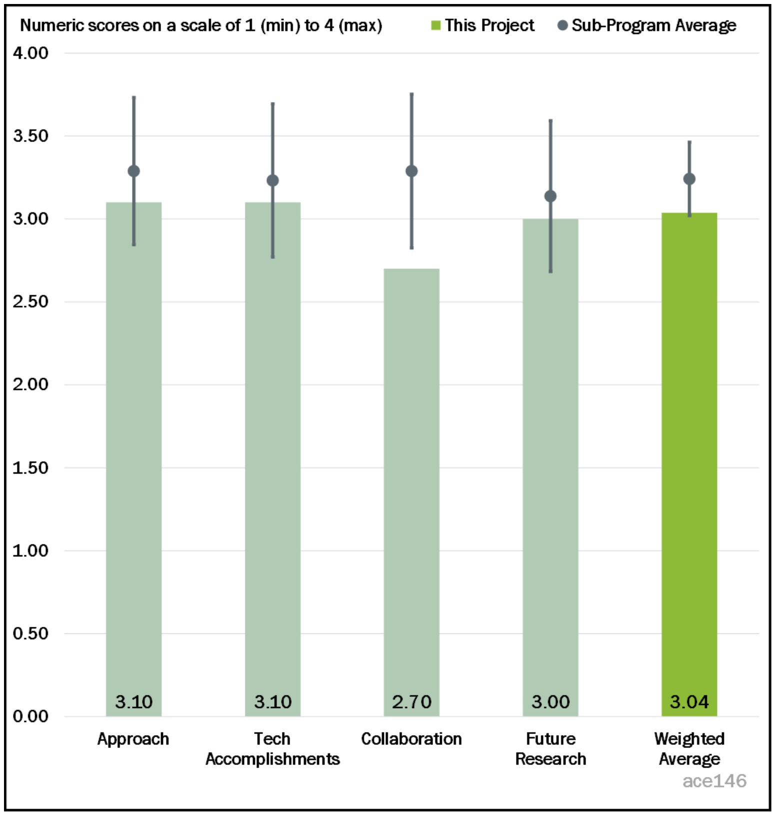

Figure 1-30 - Presentation Number: ace146 Presentation Title: Direct Numerical Simulation (DNS) and High-Fidelity Large-Eddy Simulation (LES) for Improved Prediction of In-Cylinder Flow and Combustion Processes Principal Investigator: Muhsin Ameen (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Overall, the work is well designed and planned. The approach to cross-correlate results (shown on Slide 7) is particularly excellent, and the plan to make sure the project results can be usable by industry is excellent. A minor concern is that while the work plans to identify the root causes of cyclic variability, the approach to doing so should be laid out more clearly. The presenter mentioned that the project hopes to use machine learning to do so, but a clearer and more explicit plan would be helpful.

Reviewer 2:

The project addresses the barrier of understanding and mitigating cycle-to-cycle variations and cold-start emissions, and using cutting edge simulation approaches. Leveraging DNS and large-eddy simulation (LES) would certainly be value added in understanding current limitations as well as planning to further it.

Reviewer 3:

While the reviewer appreciated the importance of super high-fidelity simulations to provide benchmarks against which to compare more affordable simulations, it is still not clear how results from this work will be used to develop sub -to improve engineering level simulations.

Reviewer 4:

Has the team considered validating the high-fidelity model against port flow simulations spanning a range of valve lifts to verify bulk flow parameters, such as discharge coefficients, mass flow rates, etc.? These types of validations are important to industry and help build confidence in the tool. Also, it would be interesting to use the tool to simulate the breakdown process of tumble flow to turbulence and compare with RANS and large-eddy simulation (LES) models. Additionally, will the team consider simulating sprays using a full Eulerian approach?

Reviewer 5:
Some key technical barriers of incomplete understanding of fuel-air mixing, stochastic combustion, and cold-start emissions are briefly mentioned. This project is to develop methodologies of accurate ICE flow analysis and combustion and emissions modeling through multi-fidelity turbulent combustion flow analyses. However, the reviewer did not understand why multiple in-house codes have to be used. These codes do not look suitable for solving realistic engine geometries within a reasonable time frame throughout the project. It seems unreasonable to invest heavily in a research-oriented code like Nek5000 just to provide some DNS data for a wall heat transfer model. There are a couple of commercial codes available now for LES analysis in real engine situations and the vendors usually open for co-development on sub-models, and this would provide engine OEMs with one of the valuable tools to improve engine efficiencies.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The team is demonstrating the capability for next level, state-of-the-art simulations.

Reviewer 2:
Both ANL and SNL made meaningful progress on ICE relevant flow/spray/extended coherent flamelet model (ECFM) combustion modeling and soot onset/flame propagation, respectively.

Reviewer 3:
The identification of shortcomings in soot models will hopefully lead to improvements because this is the most difficult thing to simulate. In order to achieve accurate soot modeling results, all elements of the simulation must be correct: airflow, fuel injection, vaporization, mixing, wall films, combustion chemistry, and then finally soot formation.

Reviewer 4:
The reasons for project delays were not discussed. The progress to date is nonetheless encouraging and promising.

Reviewer 5:
The project has made a nice progress in LES of the reference engine as well as DNS. ECFM implementation is not very impressive, as the model has been around for decades and it has limitations. It is worthwhile for the PI to justify such an effort.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
It looks like the project is in good collaborations within PACE and with external collaborators.

Reviewer 2:
Overall, it looks like the collaboration was done well with PACE teams and external collaborators, mostly using the Nek5000 code.

Reviewer 3:
The team would benefit by engaging an OEM partner.

Reviewer 4:
The approach of developing sub-models that can be provided to engineering level simulation developers may not work out if there are incompatibilities in the approach. What if commercial software developers were included as collaborators to ensure that sub-models are developed to work with commercial codes?

Reviewer 5:
This appears to be a collection of unconnected efforts with no coherent plan for integrating them or collaborating among them. The three efforts are aligned with the overall PACE effort, but they are not clearly coordinated with each other.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future work is appropriate and logical.

Reviewer 2:
The team is responding to past reviewer comments by working on coupling to engine CFD codes.

Reviewer 3:
What is the timeframe for development of sub-models that will be useful for commercial CFD codes?

Reviewer 4:
It is good for the project team to complete implementing spray-ignition-combustion models in FY 2020 and try to execute multi-cycle LES on the Sandia optical direct injection spark ignition (DISI) engine in FY 2021. It is not very clear what the project team plans to do for the development of an open-source platform for sub-model development, but it seems like a right direction.

Reviewer 5:
It is not very clear what the CONVERGE simulations will add a value to. The major goal of the project is to develop and leverage Nek5000. Please specify the connection between the efforts.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Full DNS in engines with moving valves and piston is groundbreaking.

Reviewer 2:
This work is fully aligned with DOE's objectives and will provide tools for industry to improve the efficiency and emissions of internal combustion engines.

Reviewer 3:
This project supports overall DOE objectives in attaining higher engine efficiency for diluted SI combustion through the development of sub-models for combustion, emissions, etc.

Reviewer 4:
This project is very much relevant to the DOE objectives to further understanding cycle-to-cycle variations and cold-start emissions and to mitigating them for more efficient and cleaner engine development.

Reviewer 5:
Improved simulations will contribute to better engine design tools that will help improve engine efficiency.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources for the project are sufficient for timely execution of the project milestones.

Reviewer 2:
Progress is being made, and the project has access to adequate computer cores.

Reviewer 3:
The project looks to have sufficient funding.

Reviewer 4:
Slide 6 suggests the project is linked to the Exascale Computing Project (ECP). Is there computer time reserved for ECP solvers? A project of this nature should not be thwarted due to lack of computer resources.

Reviewer 5:
The DNS analysis for a realistic engine geometry at relevant operating conditions is prohibitively costly with Nek5000. The reviewer did not mean more support on this code development for this project is necessary but had a concern about the overall approach and efficiency in using the code.

Presentation Number: ace147
Presentation Title: Mitigation of Knock and Low-Speed Pre-Ignition (LSPI) for High-Power Density Engines
Principal Investigator: Jim Szybist (Oak Ridge National Laboratory)

Presenter

Jim Szybist, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

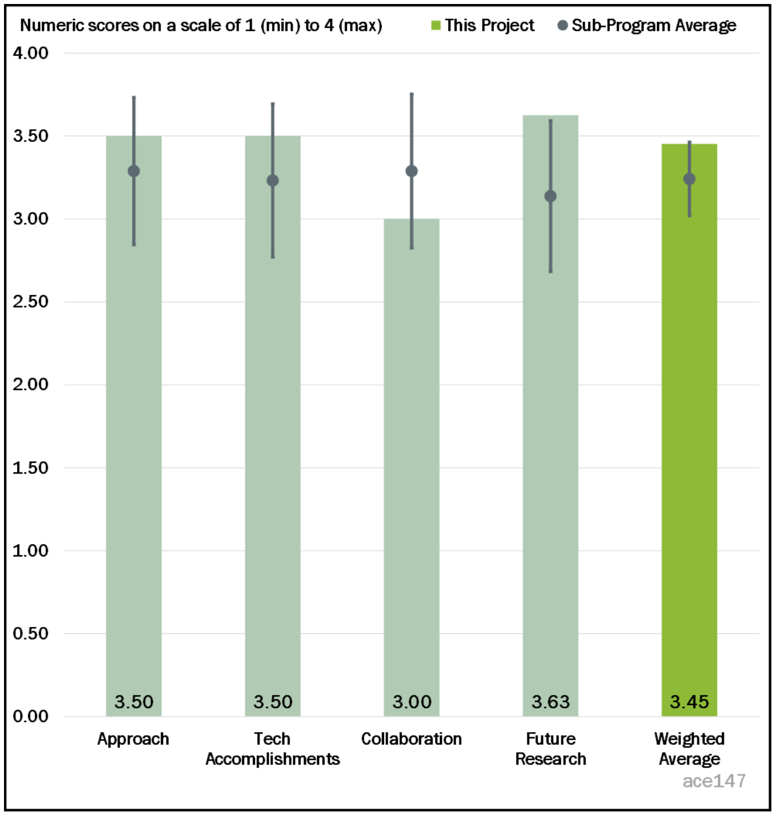

Figure 1-31 - Presentation Number: ace147 Presentation Title: Mitigation of Knock and Low-Speed Pre-Ignition (LSPI) for High-Power Density Engines Principal Investigator: Jim Szybist (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The two projects presented are each individually very well designed and planned and are addressing key technical barriers that inhibit further improvement in spark-ignition engine efficiency. This reviewer noted that the two efforts are not really connected to or integrated with one another.

Reviewer 2:

The approach appears well suited to addressing the technical barriers for knock mitigation and fuel-oil influences on LSPI.

Reviewer 3:

The approach to this work is outstanding. The PIs have recognized that there is a measurable difference in knock mitigation between catalyzed and uncatalyzed EGR. It may be beneficial if the PIs had access to a CFR engine capable of running catalyzed and uncatalyzed EGR. This would allow them to vary the pressure-temperature (P-T) trace in both the beyond-MON and beyond-RON regions into the knocking regime without damaging the engine.

Reviewer 4:

The methodologies used here to investigate knock and LSPI are sound, following good scientific practice to isolate variables of interest and separately interrogate various factors influencing the system.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
A good sweep of pre-TWC versus post-TWC EGR influence on knock limited combustion phasing was presented. Initial results from LSPI fuel-oil interaction study were also presented.

Reviewer 2:
Even with the COVID-19 shutdown, the researchers have made significant progress in their research.

Reviewer 3:
The assessment of EGR effectiveness as a function of engine load and speed is highly relevant and a strong technical result. The LSPI task is conceptually interesting but does not have substantive results yet.

Reviewer 4:
Both projects appear to be on track and progressing well. With regards to the EGR project, the reviewer had two minor suggestions. First, the team should consider an EGR mixing approach that more closely approximates what would occur in a real implementation, e.g., cooling the EGR to a specific temperature and mixing it with fresh air that is also at a specific temperature so that as EGR rate increased charge temperature would also increase. While the current approach is cleaner and easier to interpret, the effect of increased charge temperature in a real application could outweigh the benefit of the EGR.

Second, while this reviewer applauds the ability of the PI to find creative ways to create plots, such as those on Slide 11, a concern is that some information that is important is lost with this current approach. Specifically, the extent to which combustion variability (and other engine limits, if applicable) change with EGR rate also need to be communicated along with the knock benefit. The LSPI project is not as far along but has made promising progress.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The team is well coordinated and complementary. The presentation was very well structured, with just enough focus on the collaboration for it to be understandable without detracting from technical content time.

Reviewer 2:
The project team has good coordination (work in the same lab), but it may be beneficial for the team to have some outside research or evaluation from groups such as USDRIVE, USCAR, and/or the Coordinating Research Council (CRC).

Reviewer 3:
Although PACE is a coordinated effort and the tasks here fall in scope, the demonstrated collaborations with other National Laboratories are seemingly less substantial than is seen with other projects. In particular, the LSPI task does not identify specific collaborations contributing to its outcomes.

Reviewer 4:
The two projects that were reviewed are not integrated with one another but do appear to be well aligned with the overall PACE effort and well coordinated with external collaborators. This reviewer noted that exactly how the machine learning work is or will be integrated was not really discussed.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The scheduled future work is both appropriate and very well planned.

Reviewer 2:
The future research plan is logical to elucidate the impacts of the exhaust constituents on knock.

Reviewer 3:
Future work plans lack specificity but appear to generally be in line with the tasks and their current state of progress.

Reviewer 4:
Causes of increased EGR effectiveness with aftertreatment with a TWC are unclear. It is not clear what individual compound or combination of compounds cause knock mitigation. The researchers should investigate the effect of CO and NO on knock.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is fully aligned with DOE objectives and is addressing key barriers that prevent further improvement in spark-ignition engine efficiency.

Reviewer 2:
Both the knock mitigation work and the LSPI work directly contribute to DOE's PACE project goals of developing models that can accurately predict knock in modern SI engines and developing phenomenological models for LSPI.

Reviewer 3:
Minimizing SI knock will reduce the amount of fuel enrichment (saving fuel) and possibly enable further engine downsizing and boosting.

Reviewer 4:
It is important to understand how to mitigate knock to increase the fuel economy of ICE vehicles. ICEs will be around for at least two or three decades so it is important that we understand EGRs effect on knock.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project resources are sufficient for timely completion of the planned work.

Reviewer 2:
The researchers appear to have sufficient resources to complete their work. They have made excellent progress with the resources they have.

Reviewer 3:
The resources for these tasks are commensurate with their planned work and contributions to the PACE effort.

Reviewer 4:
The team resources appear to be well matched for the investigation.

Presentation Number: ace148
Presentation Title: Overcoming Barriers for Dilute Combustion
Principal Investigator: Brian Kaul (Oak Ridge National Laboratory)

Presenter

Brian Kaul, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

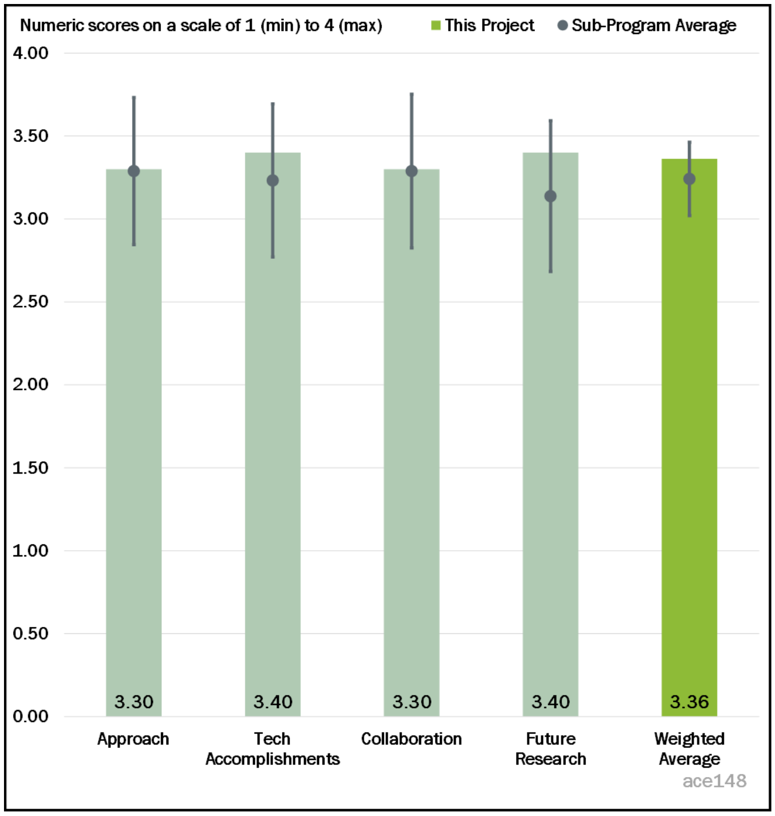

Figure 1-32 - Presentation Number: ace148 Presentation Title: Overcoming Barriers for Dilute Combustion Principal Investigator: Brian Kaul (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The collaboration is focused on addressing the multitude of challenges associated with the barriers of extending dilute combustion. Using ML to explore for insight into predictive capabilities for cyclic variability is full of challenges and complexity, but interesting, and, if successful, will be a tremendous advancement.

Reviewer 2:

All the topics in this project are highly relevant to industry. Please provide more information about the geometry of the igniters to see if they could be fitted in an automotive engine.

Reviewer 3:

Ignition system development for flame propagation combustion systems is an important pathway toward improving engine efficiency in the marketplace. The work needs to go beyond lean limit dilution tolerance tests to answer critical questions necessary for commercialization: how does the igniter behave under cold-start and catalyst heating conditions, what is the tolerance to combustion phasing retard for torque reduction during shifting, does the igniter function during a cold start at -40°C, and others? It is not clear how each of the three projects presented relate to one another.

Reviewer 4:

This is a solid method exploring different advanced plasma ignition systems and using ML to investigate the possibilities of control closed crankcase ventilation (CCV) to push the dilution limit. The PACE surrogate development seems more challenging than expected. Should the team rethink the methodology? Why not simply use a real fuel and use a surrogate or a real fuel chemistry in modeling?

Reviewer 5:
The approach on the three distinct tasks seems to be okay. They are all three fairly different tasks, however. It seems like the approach of using a single-cylinder engine, which is typically very much a steady-state device, for the next cycle ACI control is flawed. A real-world, multi-cylinder engine approach would likely be preferred if continued ACI research is warranted or desired by PACE.

How is the focus on ACI and lean gasoline combustion relevant for automotive applications today? As electrification increases for ICE powertrains and the displacement of ICE powertrains, it is clear that the ICE operating range and ACI/LTC/homogeneous charge compression ignition (HCCI) opportunity/region is becoming irrelevant. Efficiency improvements in three-way-catalyst capable gasoline combustion systems seem to be more of a relevant focus.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented that the project is on track according to Slide 4.

Reviewer 2:
There is very good progress on various fronts. The reviewer understood the challenge between different topics, but still encouraged more interactions between PIs on the team.

Reviewer 3:
The work of trying to identify an appropriate surrogate fuel is very important and their efforts toward this end are quite positive, even though they are not completely there. The work on ML is showing some encouraging results but still has a long way to go. Even if bringing the full power of supercomputing fails to resolve cyclic variability into predictable behavior, the knowledge will have been important.

Reviewer 4:
The ignition system accomplishments are excellent and clearly benchmark the state-of-the-art lean-limit extension. Why is there not a pre-chamber type ignition system in this work? Is it elsewhere in PACE? Pre-chambers are a well-known (more than 50 years), robust, lean combustion ignition system used throughout the reciprocating natural gas industry.

The machine learning and Bayesian cyclic variation control algorithm development looks to be making good progress as evidenced by the application and analysis of multiple engine operation data sets. How are the physical sources of variation being linked to the observed SI cyclic variability? Or rather, how is the team linking the observed sources of variation to control variables or design variables? Can the team actually effect a change based on the team's ML predictions with the physical engine technology?

The Crank angle at 50% mass fraction burned (CA50) control and next cycle control accomplishments seem like very good technical work; the reviewer just questioned the value of this low load ACI focus and the value of controls work on a single-cylinder engine. The RD5-87 fuels work looks to be achieving the milestones and producing very good data for the PACE program.

Reviewer 5:
The Transient Plasma Systems nanosecond repetitively pulse discharge (NRPD) ignition system is stuck in a perpetual research phase. Additional studies showing combustion benefits are not required; these have been done for 5 years. What is needed is progress toward commercialization, and there is no evidence of this.

Regarding double direct injection–partial fuel stratification (DDI-PFS), it is convenient to set very high intake air temperatures in a lab environment, but if we think ahead to a transient vehicle application, what intake temperature response rate is required at different loads to support the strategy? Additional incremental steps to improving indicated thermal efficiency are not the pathway to implementation, but instead the barriers, such as transient response of boundary conditions and tolerance to the variability of market fuels, should be addressed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer very much liked the collaboration that is an integral part of PACE. The integrated efforts of the various National Laboratories and stakeholder participants is greater than the sum of previous independent efforts.

Reviewer 2:
Collaborations on each of the three projects are good.

Reviewer 3:
The team has good synergy between ignition (Ekoto), pattern recognition (Kaul), and CA50 control of gasoline compression ignition (Dec). Please show if GCI can be used at high loads.

Reviewer 4:
Overall, the collaboration is good considering the difficulties between different topics. But, more interactions and coordination are encouraged.

Reviewer 5:
The coordination seems adequate, but these are three very different tasks. More coordination of how these relate to each other may be necessary, or how they should be moved closer to other activities within PACE. It looks as if each specific task has reasonable collaboration with its own relevant partners.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer affirmed very thorough future work.

Reviewer 2:
Using the barrier discharge igniter in a pre-chamber is very interesting. The reviewer looked forward to seeing the results of this project.

Reviewer 3:
The reviewer asserted that identifying an appropriate surrogate fuel should remain a high priority.

Reviewer 4:
Slide 4 and Slide 20 give enough detail to show that the future research is reasonably planned and thought out with minimal risk.

Reviewer 5:
Future work needs to broaden the scope to address questions related to commercial implementation over a broad range of operating conditions and not another dilution tolerance sweeps or incremental increase in indicated specific fuel consumption (ISFC).

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is highly relevant to the overall DOE objectives. This is an important area to explore to keep pushing for efficiency improvement.

Reviewer 2:
This project is highly relevant to the DOE objective of enabling dilute gasoline combustion. It is also highly relevant to industry. The next cycle prediction (Kaul's work) would be extremely useful to improve engine performance.

Reviewer 3:
The close collaboration between the different participants and their connection to DOE and Industry, through USDRIVE and USCAR via the various tech teams, keeps the focus of this work relevant.

Reviewer 4:
Improvements in engine efficiency addresses DOE goal of reduced energy consumption.

Reviewer 5:
It is clear that improving ignition systems can improve engine efficiency in either lean-burn or EGR-stoichiometric operation. It is also clear how the machine learning task contributes to realizing higher efficiency combustion strategies in the real world. It is not completely clear if the multi-mode ACI task is relevant, but the fuel-specific areas of this task are relevant to the broader PACE goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project overall is on track with good resources.

Reviewer 2:
The resources and the team in place appear to be adequately resourced to tackle the challenges of this project.

Reviewer 3:
It appears to the reviewer that funding is adequate.

Reviewer 4:
The budget looks to be appropriate for the future tasks and future milestones. Additionally, the National Laboratory facilities and the HPC resources are clearly sufficient.

Reviewer 5:
There was no indication that the funding level was insufficient.

Presentation Number: ace149
Presentation Title: Cold-Start Physics and Chemistry in Combustion Systems for Emissions Reduction
Principal Investigator: Scott Curran (Oak Ridge National Laboratory)

Presenter

Scott Curran, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

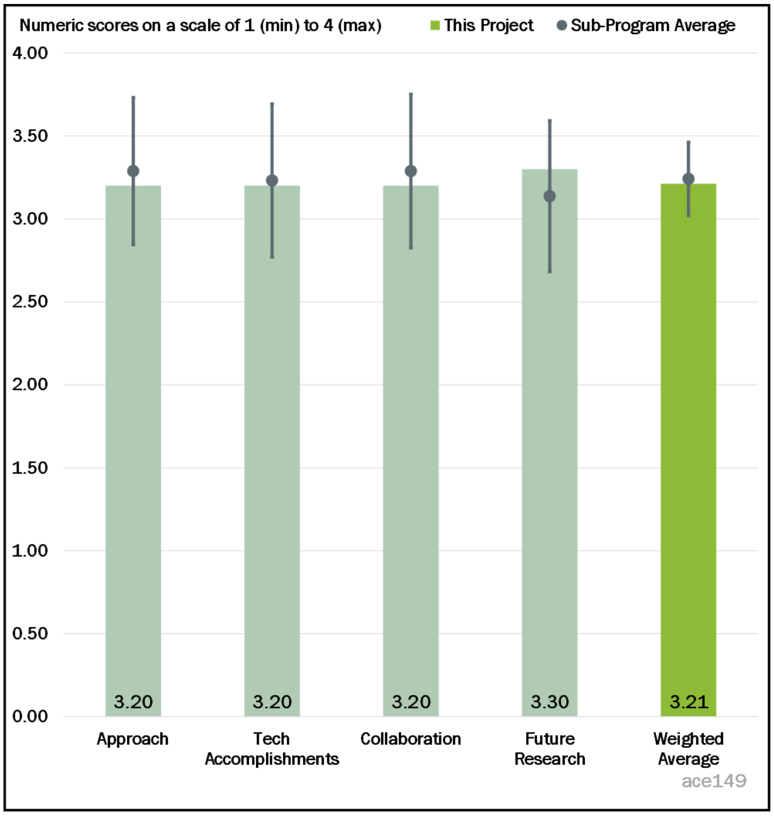

Figure 1-33 - Presentation Number: ace149 Presentation Title: Cold-Start Physics and Chemistry in Combustion Systems for Emissions Reduction Principal Investigator: Scott Curran (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project team well understands technical barriers to the reduction of cold-start combustion and emissions. The project is planned well for addressing key issues of cold-start emissions through single cylinder engine testing and numerical simulation of a PACE surrogate with PAH mechanism. It seems feasible that the project can be executed well in both testing and simulation, and the project team could provide invaluable information to overcome the barriers. However, it is not certain if soot modeling can be accurate for a wide range of cold-start operation as the current surrogate fuel showed a big difference with the reference fuel RD5-87 in higher exhaust heat flux range.

Reviewer 2:

The approach to use both simulation and experiment to better understand the physics of cold start is sensible. This project is using engine experiments, benchtop experiments (at Yale), and simulations—this should be a recipe for success. It also appears that some work on the Argonne engine to allow for proper exhaust cam timing would benefit this project and bring it more in-line with the other aspects of the project.

Reviewer 3:

The focus on development and understanding around cold-start performance is a relevant topic. The challenges, and clear technical barriers, are not laid out in great detail, though this may largely be a result of the overall PACE focus on experimental programs providing data to build out model capabilities. Clarity on what barriers need addressing within the modeling work are not highlighted. This again may be a function of the overall PACE effort and structure of the AMR presentations. On an individual project basis, the approaches being taken are on target and, as best can be ascertained from the level of detail allowed in this format, feasible for the resources and tools available.

Reviewer 4:
The project may be overreaching on objectives and experiencing a creep in scope by tackling active pre-chamber ignition for cold start and the development of a transient test protocol. The project should first aim to understand the physics and chemistry of the incumbent cold-start techniques being employed by OEMs. This basically involves injection (quantity and timing), spark timing, and other basic engine control variable changes to speed up catalyst heating. The ACEC Cold Start protocol is a very good place to start gaining this understanding. Then, later, advanced ignition systems and transient understanding can be developed.

Reviewer 5:
The focus on catalyst heating conditions is critical for any new combustion technology to enter production. The approach is generally solid, but the reviewer had some concerns. The ANL heat flux sweep is anemic. Typical turbo engine without an auxiliary method to heat the catalyst would need to operate in the approximately 8 kilowatt (kW)/L range. The ACEC protocol recommended range of 3-10 is to see how capable the approach is across this range. Where does the stability begin to fall apart? The ANL baseline approach might benefit from a more sophisticated injection method (split injection, stratified injection) to enable higher heat fluxes. The spark around top dead center (TDC) is typical for a PFI type of homogeneous charge system. The reviewer commented that, typically, there is an inability to retard spark past TDC without combustion stability issues.

The reviewer liked seeing the skip fire approach. Steady state cold fluids are known to underestimate the emissions that depend on wall impingement. Internal temperatures are too high. It does a reasonable job at capturing the stability and heat flux capability though.

With respect to the operating conditions for soot, catalyst heating conditions are important but maybe more important are the higher loads seen around 20-30 seconds on the FTP cycle. The customer requests torque. Mass flow, fuel flow increases, and the combustion chamber is still relatively cold. Consider adding a higher speed and load condition to the work.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Overall, the progress that has been made is very good. Both steady-state and transient operations of single cylinder engines (SCEs) at three participating National Laboratories were being performed. ANL made progress in testing baseline SI cold-start test although exhaust heat flux range was low. ORNL characterized cold start emissions using both baseline and PACE surrogate fuels on a converted SCE from a 4-cylinder engine. SNL tried to test transient cold start operation, which seems the most valuable test but also hard to control the operation. LLNL developed a PAH mechanism and validated against data from diffusion flame tests.

Reviewer 2:
There are good accomplishments considering a Q3 of FY 2019 start.

Reviewer 3:
The accomplishments in this project have been pretty good—the engines, burners, and simulations have produced some interesting results and some understanding has been gained. However, exhaust heat flux in the Argonne engine is well below the target (due to a fixed cam not allowing EVO), limiting its effectiveness. But, the resources applied do not seem to match up with expected results. There still seems to be some improvements to be made in the experimental validation and matching results from facility to facility.

Reviewer 4:
The Oak Ridge data for the ACEC Cold Start test look very much on par and as expected. Good to see the PACE surrogate performing well. Can this engine be used to study the effect of injection and spark parameters on engine performance during the ACEC Cold Start test? The Argonne data do not seem to be in the ballpark of the ACEC Cold Start test expectations. Perhaps changing the cams will resolve the situation. It is suggested that the guidelines set for the engine performance for the test protocol be first met satisfactorily before investigating an active pre-chamber advanced ignition system.

Reviewer 5:
The 2019 milestone of commissioning a series of off-the-shelf instruments is viewed as a very weak milestone, especially since it is the only listed milestone for a project funded at $400,000. Moving forward, this reviewer would have liked to see a more meaningful measurement of progress.

The reviewer was concerned to see the lower than desired exhaust heat flux in the ANL engine experiments. This should be rectified so that all experiments across the different National Laboratories are proceeding with similar cold-start conditions. The reviewer realized that this issue was not likely apparent ahead of experiments, but it should be addressed and corrected moving forward.

There is solid initial work at ORNL to establish and characterize baseline cold-start conditions in their engine. There are significant variation and scatter in some of the emissions data presented from this baseline testing on Slide 10. This would be good to resolve in future experiments and characterize whether this is due to combustion and fuels, or simply experimental uncertainty. Results from SNL efforts focus on new experimental technique development. Future results need to focus on phenomenon explanation and details, not further experimental tweaks.

Yield sooting index (YSI) measurement validation is “complete,” but the simulated YSI for tetralin, a key component planned for use to represent heavy, high boiling point components, is off by nearly 35% from the experimental measurement. It is not clear how this is a successful validation, given the offset and importance of this molecule to the PACE surrogate. Does matching engines improve validation data? It may improve validation on a single geometry, but CFD sub-models should be agnostic to engine geometry and type.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There appears to be excellent coordination and collaboration among the team members on this project. The benchtop and simulation work appear to be particularly well coordinated. The engine progress was also significant, and the communication appeared to be good.

Reviewer 2:
There are four National Laboratories participating in this project, and they are all working toward a common goal for the PACE program. They seemed to work closely internally and also externally for exchanging experimental data for model validation work.

As far as testing all different SCEs at different sites goes, they need to have a common definition or calculation of test data collection and processes for such parameters as indicated mean effective pressure (IMEP), brake mean effective pressure (BMEP), burn rate, CA50, cycles for coefficient of variation (COV) IMEP, exhaust heat flux, NO_x correction, soot measurement, etc., for testing all different SCEs at different sites.

Reviewer 3:
Very good collaboration exists between ORNL, ANL, and Sandia for the engine experiments. Modeling efforts have started but are experiencing some difficulties (ACE145).

Reviewer 4:
The structure of PACE promotes excellent collaboration. Be sure to stay connected to the fuel spray portion of PACE. Fuel impingement is critical for HC and soot production during cold start. Is the baseline wall wetting (due to the injection approach) a good place to start to look for improvements? Is your baseline wall impingement representative of a typical cold-start calibration? Wall impingement from an intake stroke injection will be different from a late compression stroke injection that might be employed to stabilize combustion during catalyst heating.

Reviewer 5:
Collaboration appears mostly on paper for this project. The different National Laboratory efforts are focused on completely different subjects under the same general focus area. Very little collaboration across the team is apparent. This may stem in part from the overall PACE structure and how presentations were bundled for this AMR. However, overall participation in the PACE umbrella program should not be viewed as the sole necessary collaboration across project teams. Some outside collaboration is noted, but generally limited. For some of the external collaborations, it is not clear that the collaborative work applies to this particular effort.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Selected future research topics from all four teams look quite reasonable and moving forward to meet the project goal and support PACE program goals.

Reviewer 2:
The proposed future work appears to be fairly well coordinated and connected to the progress made this year. The new exhaust manifold for the ORNL engine should help provide improved measurements. The pre-chamber results from the Argonne engine should be especially interesting if they can get it up and running properly.

Reviewer 3:
The reviewer said to continue to pursue a skip fired protocol.

Reviewer 4:
Presumably the modeling efforts, once some of the initial challenges mentioned in ACE145 are resolved, will keep in step with the experiments.

Reviewer 5:
Proposed future work looks reasonable as a next step for this particular area, although the connection to CFD model development is not immediately clear. As the effort moves forward, it will be useful to detail how the results from these efforts feed into the model development and enhancement. The parametric study on pre-chamber geometry, while addressing a key potential barrier to pre-chamber adoption, seems like it is only part of the necessary study. Engine hardware design is always a compromise between different driving factors. In this case, does a pre-chamber optimized for cold start still deliver the lean or dilute operation performance that is a prime driver for using pre-chambers? This effort should be ideally expanded to demonstrate if there is a tradeoff between cold-start performance and the other enabling characteristics for pre-chamber use.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project supports the overall DOE objectives in providing low emissions dilute combustion strategies in cold start and operation and modeling capabilities.

Reviewer 2:
Yes, this project directly supports the overall DOE goals—reducing cold-start emissions by better understanding the fundamental mechanisms behind the formation of fuel films and locally rich operation.

Reviewer 3:
The project is directly connected to DOE objectives on improving vehicle emissions. As engine and aftertreatment effectiveness increase and emissions regulations grow ever more constraining, the bulk of emissions occurs during cold-start operation. Understanding details of operation during cold start is crucial for developing strategies to reduce emissions further under these conditions.

Reviewer 4:
The reviewer asserted that the project is directly relevant to putting clean and efficient ICEs into LD fleets.

Reviewer 5:
Understanding the base spark ignition cold start is more important. The application of an active pre-chamber is of lower priority.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The amount of effort, facilities, and funding appears to be consistent with a project this size.

Reviewer 2:
The reviewer commented sufficient. The PI did not indicate additional resources would improve the outcome.

Reviewer 3:
Each team seems to have adequate resources for engine testing or simulation. ANL needs to extend the engine testing range to higher exhaust heat flux but it is more on the technical side.

Reviewer 4:
Funding looks appropriate for the scale of the effort associated with each subtask. The funding going toward validation of a PAH and soot model against experimental data looks high for this particular scope. Increased funding for the pre-chamber effort should be considered if the scope increases to look at tradeoffs in design for cold-start conditions versus lean or dilute performance.

Reviewer 5:
More of the resources should be focused on understanding the baseline cold-start strategy and looking for opportunities for improvement before applying advanced ignition concepts or complicating the test protocol any further.

Presentation Number: ace150
Presentation Title: Enabling Low-Temperature Plasma (LTP) Ignition Technologies for Multi-Mode Engines through the Development of a Validated High-Fidelity LTP Model for Predictive Simulation Tools
Principal Investigator: Nick Tsolas (Auburn University)

Presenter

Nick Tsolas, Auburn University

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

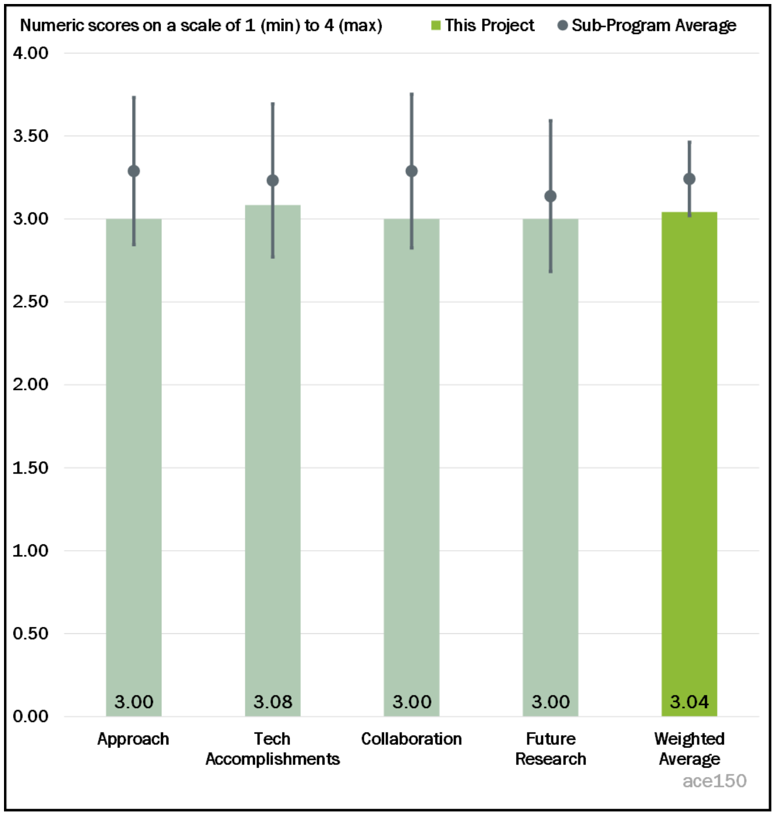

Figure 1-34 - Presentation Number: ace150 Presentation Title: Enabling Low-Temperature Plasma (LTP) Ignition Technologies for Multi-Mode Engines through the Development of a Validated High-Fidelity LTP Model for Predictive Simulation Tools Principal Investigator: Nick Tsolas (Auburn University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said remarked that this is a very solid approach to developing an LTP model and comparing the current available commercial software.

Reviewer 2:

Overall, this work is well designed and is addressing key technical barriers that could allow for the development of advanced ignition systems. Each of the four work packages is very well planned and executed.

It is not clear how the four efforts in this work are interconnected, if they are in fact interconnected at all. If they are, it would be beneficial to communicate these connections visually to show how the four efforts ultimately are integrated to help develop improved ignition systems. If they are not interconnected, this reviewer suggested trying to integrate portions of them into one another, even if it is at the latter stages of the validation or trial efforts.

Reviewer 3:

The combination of simulation and experimentation, including combustion vessel studies, is an acceptable overall approach but seems to stop short of engine validation. Still, the technical, phenomenological insights should be valuable. The U.S. DRIVE Roadmap recommends evaluating plasma ignition, among others. This presentation would be better if it included a slide on the overall status of plasma ignition and what other barriers besides simulation exist. For example, are these systems in use and what is the record of success? The approach is missing an industry collaborator or potential manufacturer.

Reviewer 4:
It is unclear why the team needs both an exascale solver based on AMReX and VizGlow. Can one solver be chosen to avoid proliferation and development of different solvers?

Reviewer 5:
This project is aimed at developing a computational tool for simulating LTP ignition of hydrocarbon fuels. It includes both experimental and computational pieces in the overall approach. It is a bit unclear to the reviewer why two computational frameworks—AMReX and VizGlow/CONVERGE—are needed. Are both tools adequate for the project? Both tools have advanced mesh refinement (AMR) and have significant parallelization capability. It needs to be made clear that the work in both codes is not redundant. The reviewer's fear was that AMReX is developed for this project, but then this tool is not transferred or used by OEMs actually designing engines. The experimental approach appears to be reasonable.

Reviewer 6:
This is a fairly new project and the proposed approach seems plausible. A question was raised during the discussion whether VizGlow work and AMR software work are duplicative, for which the PI replied that one of the co-PIs believes that VizGlow has some inherent issues. This reviewer indicated that since the plasma ignition models are not well understood, it is a worthwhile endeavor to use both tools; but, at the end of the work, the team should point out the strengths and weaknesses of each tool as the predicted results will be validated with experiments.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project is in early stages, but the team members have exhibited good progress and have generated useful results. The experimental apparatus is moving along well.

Reviewer 2:
This project kicked off in January 2020 and was impacted by the COVID-19 pandemic. While the progress is behind the planned schedule, it is progressing appropriately given the circumstances.

Reviewer 3:
Progress is limited due to the pandemic, but progress is being made on the modeling work.

Reviewer 4:
Solid progress has been made at all teams although the project just got started. Some experimental delays due to the pandemic are understandable.

Reviewer 5:
Of course, the experimental initiative has been delayed due to COVID-19; however, some progress has been made on the computational side. This project has only just started in January of this year and so not a lot of progress is expected. Having said that, chemical mechanisms have been evaluated and reduced, and some parametric studies have been performed.

Reviewer 6:
The reviewer noted that it is too early to gauge this, especially with the interruptions caused by COVID-19.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This is a very good team, comprised of two National Laboratories and two universities.

Reviewer 2:
There is good collaboration between all the teams involved in the project.

Reviewer 3:
The roles of each team member are sufficiently clear. There is some debate about which software foundation is best but seems likely to be worked out. The lack of an industry partner or advisory panel is noted. There is a private sector company pursuing commercialization of plasma ignition, also under DOE funding, which perhaps should be acknowledged.

Reviewer 4:
This project is a collaboration of two National Laboratories and two universities and is leveraging the expertise of each individual organization. Referencing prior comments, the reviewer suggested it would be beneficial to increase coordination of these efforts, or to communicate them more clearly if they already exist. Additionally, it would be helpful to engage with industry (e.g., a Tier 1 supplier of ignition systems) to inform the work and facilitate potential commercialization.

Reviewer 5:
The direct linkage of the work being conducted at the University of Texas at Austin and ANL is unclear. How do these modeling efforts overlap with each other?

Reviewer 6:
Not applicable was indicated by this reviewer.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer commented the next step plan seems reasonable.

Reviewer 2:
If complex fuels (e.g., gasoline) were able to be evaluated experimentally with the gas chromatography mass spectroscopy (GC-MS) in the Auburn work, it could be instructive to understand what a complex fuel breaks down into – even if detailed kinetic modeling is not possible for that fuel. In other words, characterization and speciation of complex fuels experimentally might inform the experiments and modeling of the simpler fuels in this work, at least based on the understanding of this reviewer.

Reviewer 3:
Only 5% of the project has been completed since the project started in January 2020, and much of the experimental effort has been delayed due to COVID-19. So, in essence, the near entirety of the project is future work and the original scope should be maintained.

Reviewer 4:
There was no “Future Research” slide, but the reviewer assumed efforts will be made to accelerate the experimental measurements when possible.

Reviewer 5:
Since the project is only 5% complete, practically all research is “future.” However, there still should have been a slide and few points made about research for the next year. The reviewer presumed this was an oversight and will be corrected next time.

Reviewer 6:
The reviewer asserted that this is one area that needs some improvement. Tables are provided with tasks and milestones, but it would be better to see more details about the future tasks, their barriers, and alternate pathways.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This work fully supports DOE’s objectives and is filling gaps in knowledge that could lead to improved engine efficiency via the development of advanced ignition systems.

Reviewer 2:
The current work is relevant to the overall DOE objectives and has the potential to contribute to different projects.

Reviewer 3:
Yes, this project supports the overall DOE objective of designing more efficient and cleaner engines.

Reviewer 4:
Technical developments from this project can assist PACE deliverables.

Reviewer 5:
Engines that use highly dilute mixtures, or attempt to ignite mixtures at very high pressures, or difficult-to-ignite fuels can benefit from better, more robust ignition systems. The U.S. DRIVE Roadmap recommended such.

Reviewer 6:
Absolutely. As we are looking for efficient engines with air or EGR dilution, it is important to understand the physics behind alternative ignition mechanisms such as LTP. The intersection of LTP and EGR will be interesting, and the emergence of radicals and EGR species and their interaction will be challenging. For example, NO_x (in EGR) is known to have an impact on ignition delay.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources and team executing this work are sufficient for achieving the project milestones in a timely fashion.

Reviewer 2:
The team has sufficient resources.

Reviewer 3:
From the amount of information that was presented to the reviewer, the reviewer believed that the resources for this project are sufficient.

Reviewer 4:
There are no resource issues except some measurement delays, which are set to resume.

Reviewer 5:
The budget information is a little vague. Is the National Laboratory funding $300,000 total, or per year, or per lab? Given that the project output is computational methods and data (not a prototype system), the resources seem satisfactory.

Reviewer 6:
The reviewer remarked that it is too early to comment as much of the project is yet to be accomplished.

Presentation Number: ace151
Presentation Title: Hierarchically Informed Engineering Models for Predictive Modeling of Turbulent Premixed Flame Propagation in Pre-Chamber Turbulent Jet Ignition
Principal Investigator: Haifeng Wang (Purdue University)

Presenter

Haifeng Wang, Purdue University

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

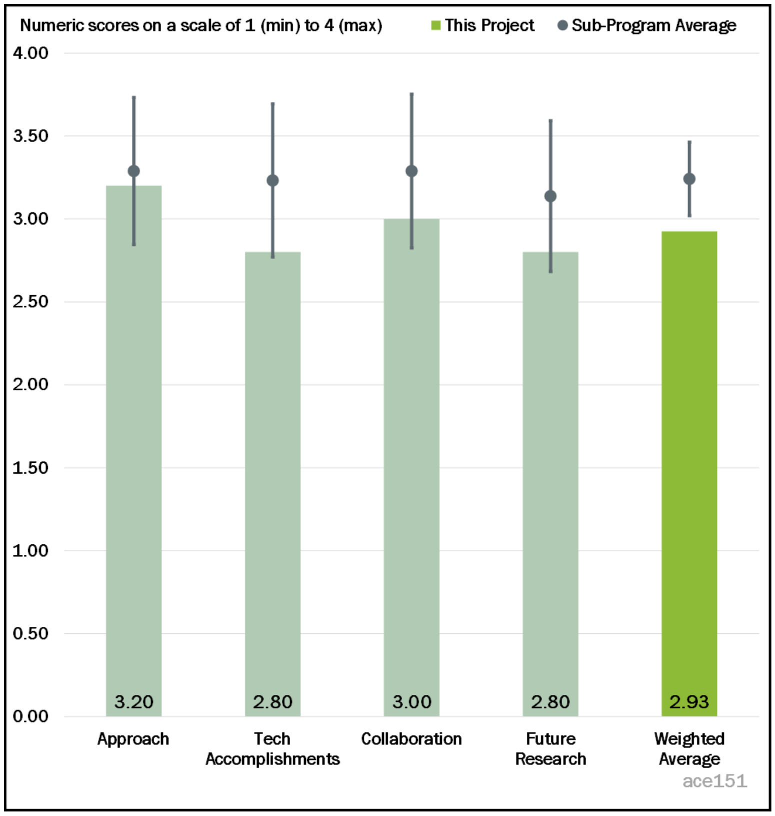

Figure 1-35 - Presentation Number: ace151 Presentation Title: Hierarchically Informed Engineering Models for Predictive Modeling of Turbulent Premixed Flame Propagation in Pre-Chamber Turbulent Jet Ignition Principal Investigator: Haifeng Wang (Purdue University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Starting from a very detailed and accurate simulation and then paring down to an engineering level simulation all the while comparing to bench rig and engine test results is an excellent approach.

Reviewer 2:

The project is well designed to improve the predictive accuracy and efficiency of turbulent combustion sub-models for the simulations of premixed flame propagation initiated by pre-chamber turbulent jet ignition, from DNS to LES to RANS. However, the newly developed model should be validated based on experimental results, in addition to DNS.

Reviewer 3:

The team seeks to leverage DNS simulations to improve LES and RANS models. However, will the proposed power-law scaling account for turbulence-chemistry interaction in the RANS framework?

Reviewer 4:

The technical barriers specified were to establish the modeling tools for rapid screening design and to build a robust ignition system with less variability. The approach of working with DNS for a turbulent jet ignition (TJI) model—LES simulation supported by statistics properties from DNS and final RANS simulation aided by the LES—is generally okay and acceptable. However, the technology transformative connections are not clear. For example, what type of specific data and specific sub-models, other than power-law scaling, will be utilized from DNS to LES to RANS and the ranges of Karlovitz number under the highly stretch flame occurring in the typical engine condition? Individual Objectives defined in Slide 3 seem to stand alone without the profound connection among them. There is no return feedback algorithm to improve the DNS sub-model development from Argonne (LES and RANS) to Purdue (DNS) as the flow chart describes in Slide 5. The reviewer indicated that the LES and RANS simulations at Argonne have a very weak connection with DNS work, especially because the targets and goals being investigated are unclear. The reviewer also indicated that feedback for each simulation to improve the sub-models being investigated was lacking.

Reviewer 5:
The reviewer worried that the approach for this project is too complex with DNS, LES, and RANS all part of the methodology. If the project were successful in taking DNS to LES, that in itself would be a success. In addition, how much more effort should we be putting into RANS models? If the goal is exascale, then the accuracy of LES simulations should be leveraged.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
This project seems to be on track, with the Q1 milestone completed and the others on schedule for this year.

Reviewer 2:
The project started early this year. As planned, the PI completed hypothesis testing of the existence of power-law scaling of sub-filter scaling mixing in high-Karlovitz turbulent jet flames from both global and local perspectives.

Reviewer 3:
It would be good to show a comparison of predictions of a flame with and without the addition of the power-law scaling.

Reviewer 4:
The reported progress does not seem to be very extensive and is not understandable by someone who is not a CFD expert.

Reviewer 5:
Technical progress and accomplishment on this project are too early to judge since this project has just started in January 2020. However, it looks like DNS work mainly focuses the power-law scaling sub-model development under the high-Karlovitz turbulent premixed flame in order to provide the statistics properties for the LES simulation only. In reality, most of engine combustion conditions are under high pressure and lean combustion, which may significantly affect the burning process at the flame front due to the non-unity Lewis number effect. The power-law scaling model seems to be overly simplified, and the effect of Lewis number on the DNS flame simulation needs to be considered when the high mixing occurs at the flame interface.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration with ANL for engine data and a Purdue colleague for bench rig data is good.

Reviewer 2:
The collaboration level in simulation seems to be adequate between Purdue and Argonne while the reviewer anticipated that it may be problematic for DNS validation at engine conditions due to the lack of high-pressure TJI data.

Reviewer 3:
The Purdue-Argonne team is a strong one. Sandia is also listed a partner, but the reviewer did not see any of the budget going toward it. How do they fit in?

Reviewer 4:
The project started early this year, so it is difficult to assess the level of collaboration. The reviewer hoped that PIs can strengthen the collaborations with the auto OEMs or other companies who are working on TJI.

Reviewer 5:
Is the modeling work targeting a specific type of TJI or is it generalized? Can the species composition in the TJI rig be controlled?

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Since this is a 15-minute presentation, the presentation provided very limited information about the future plan. But, it seems well planned based on the "Milestones" of the project. Again, PIs should consider validation based on real engine results.

Reviewer 2:
The proposed future research for this project is nicely laid out in a logical and organized manner. It would be nice to see some alternate development pathways, however, especially for a project like this that relies on a fairly complex approach.

Reviewer 3:
It is not clear when work with the engineering level simulation will be undertaken. This is an important step toward helping engine developers design new engines with TJI.

Reviewer 4:
What is the plan to incorporate machine learning shown in Slide 5? What ML approach is being used and specifically how will it be linked to the RANS engine simulation? Will ANL also simulate the TJI rig?

Reviewer 5:
To the reviewer, the future plan is not concrete in a way because there seems to be a very weak connection between DNS versus LES and RANS. The reviewer believed that the future success depends on the collaboration between the experimental effort for new validation method and the work on a minimum tuning parameter model with fast turnaround of computation time, especially LES and RANS simulations.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer believed that this project does support the overall DOE objectives. This is summarized by the two U.S. DRIVE Roadmap barriers listed on the Overview slide: "Understanding and robust modeling tools for rapidly screening proposed designs based on sound metrics are lacking"; and "More robust ignition systems for lean and EGR, as well as boosted conditions that reduce combustion variability are needed". This work attempts to overcome those barriers for TJI combustion.

Reviewer 2:
TJI is another approach at enabling dilute, high-efficiency gasoline engine technology toward meeting the U.S. Department of Energy's efficiency goals. It does support DOE goals.

Reviewer 3:
The technical work has linkage to the PACE program.

Reviewer 4:
Accurate engineering level simulation tools will help engine designers develop more efficient engines, and this will help reduce energy consumption.

Reviewer 5:
From a broad perspective, the reviewer responded yes. However, in order to improve the sub-model development, experimental data validation at high pressure and high EGR conditions is needed for DNS.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer believed that the resources for this project to achieve the stated milestones are sufficient.

Reviewer 2:
The resources are sufficient.

Reviewer 3:
Resources are sufficient.

Reviewer 4:
The resources for simulation appear to be adequate.

Reviewer 5:
The team has the necessary resources to conduct the proposed research. However, the reviewer hoped DOE can provide additional funding to support model validation with real engine results.

Presentation Number: ace152
Presentation Title: Development of High-Fidelity and Efficient Modeling Capabilities for Enabling Co-Optimization of Fuels and Multi-Mode Engines
Principal Investigator: Matthias Ihme (Stanford University)

Presenter

Matthias Ihme, Stanford University

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

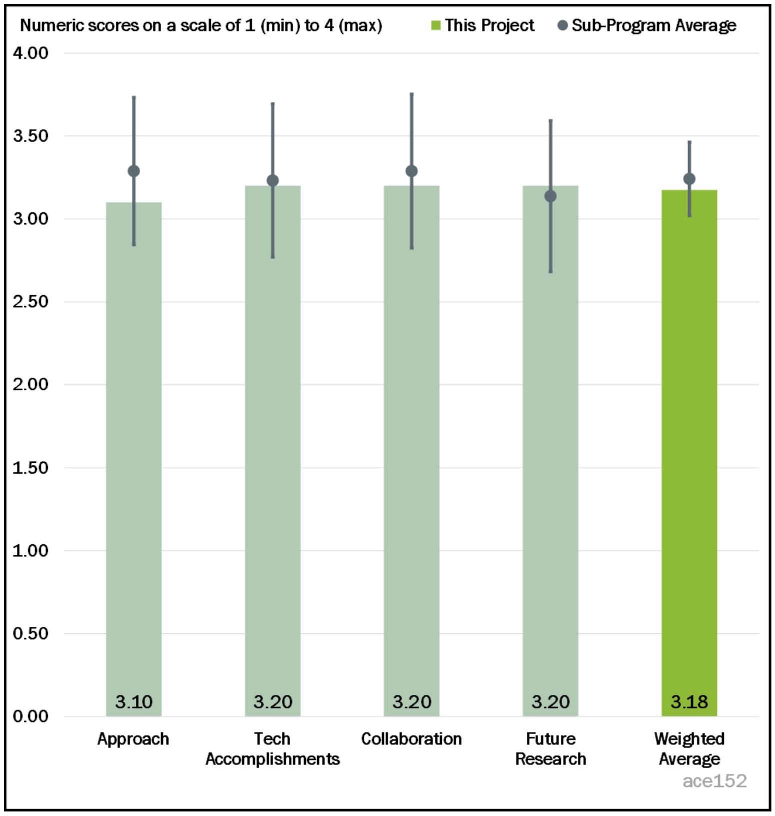

Figure 1-36 - Presentation Number: ace152 Presentation Title: Development of High-Fidelity and Efficient Modeling Capabilities for Enabling Co-Optimization of Fuels and Multi-Mode Engines Principal Investigator: Matthias Ihme (Stanford University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

A solid and efficient combustion model is definitely needed for the multi-mode combustion. The chemistry is key for high-energy ignition modeling. The approach is sound and reasonable.

Reviewer 2:

The approach is a good one and leverages the expertise of the team members well. It is particularly nice to see consideration of heat transfer taken into account in the simulations as this can be a significant loss to efficiency. The focus on high-performance computing and optimization of the methods is also critical, so coordination with Argonne in that respect is important.

The only piece of the approach that is currently missing is the lack of treatment of radiation. The PI indicated that it may not be necessary due to the dilute conditions and soot, but it is actually those dilute conditions that cause gas-phase radiation and the resultant re-distribution of temperature to be quite important. The PI pointed to the work from Dr. Dan Haworth's group—this will be important to consider going forward. Fortunately, the PI also mentioned a collaboration with Dr. Volker Sick, who has worked with Dr. Haworth's group in the area of radiation and wall heat transfer in the past. It would be prudent to determine whether gas-phase radiation will be a contributor to temperature re-distribution and then also wall heat transfer early in the project to improve the impact of the work down the road.

Reviewer 3:
Multi-mode combustion is the chief focus of DOE VTO, and the project tries to address the challenges through fundamental studies including Pareto-efficient combustion, chemical reduction strategies for plasma ignition, a non-equilibrium wall model for heat transfer, and, finally, multi-mode engine simulations on an exascale platform. All these tasks are critical, and a fundamental understanding is necessary.

Reviewer 4:
The reviewer thought this project sounds impressive, but wondered how relevant it is. For example, do we need the "Pareto-efficient combustion model" to simulate these conditions? What is the benefit of developing Nek5000 when industry does not use this tool for designing engines? Do not get the reviewer wrong, the reviewer thought that all of the work being done under this project is likely high quality—the reviewer's concern is more about if it is needed.

Reviewer 5:
Does the Pareto-efficient combustion model run on GPUs? If not, would there be a significant speed advantage? Also, how does the Pareto-efficient combustion model compare to LLNLs Zero-RK approach?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Solid progress has been made for various topics in the project.

Reviewer 2:
The project does a nice job laying out the technical accomplishments that have been completed so far by each of the collaborators.

Reviewer 3:
The team is making progress in all technical areas. The team should include a timeline or chart showing when each of the tasks will be complete.

Reviewer 4:
The project has only recently started, and the initial accomplishments in the first approximately8 months have been good. The use of methane for the multi-mode combustion simulations at the outset is a bit limiting, given the uniqueness of methane ignition chemistry and the need for more complex fuels in real engine configurations, but it is good to hear that the PIs have plans to move quickly to iso-octane. Concurrent development and implementation of models into the Nek5000 framework is important.

Reviewer 5:
The project started in October 2019 and has less than a year under the belt. About 15% of the work is completed and seems to be on track. The reviewer thought a better assessment of the progress could be done at next year's AMR.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer found very solid and extensive collaboration and coordination with other institutions.

Reviewer 2:
This is a strong team comprised of Stanford University, the University of Connecticut, and Argonne. There is also coordination with Sandia, the University of Illinois Urbana-Champaign, the French National Centre for Scientific Research, and the University of Michigan at Ann Arbor.

Reviewer 3:
There seems to be good collaboration across the team, and a good team has been assembled to tackle all of the issues outlined in the project. The reviewer encourages further interactions with Isaac Ekoto as well as the simulation team at Argonne in the area of ignition, as there has been a significant research focus in that area over the past few years as part of this portfolio. The continued connection with experimental data is important.

Reviewer 4:
This is a small team compared to several other collaborations seen in ACE. Some industry collaboration for the team would be helpful to have some ground-truthing of the results achieved here. The team should also see if there could be potential collaboration with Convergent Science or other CFD provider to see if reduced order models could be implemented in their solvers, especially for plasma ignition.

Reviewer 5:
Why is there no engagement with Argonne National Laboratory on ignition modeling? How does the proposed ignition model described here differ from what is being done at Argonne?

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The project tasks lend well to improving the Nek5000 engine simulations.

Reviewer 2:
The next steps of the project area seem logical and the work to date sets up a good foundation on which to build toward these ambitious goals. As mentioned previously, the PIs are encouraged to consider the effects of radiation, especially since the development of non-equilibrium wall modeling is an explicit goal of the project. Otherwise, the remainder of the tasks are sound.

Reviewer 3:
The proposed future work sounds reasonable. Is there a plan to merge to one platform for model cross-validation at a certain point?

Reviewer 4:
Since the project is only about 15% complete, much of the originally proposed work is still future work. As of now, the future work seems realistic and relevant. A better assessment could be done at next year's AMR.

Reviewer 5:
The team does a good job outlining the proposed future research, but again the reviewer questioned how necessary much of it is.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Absolutely. These are the kind of activities that DOE needs to be funding at the fundamental level in universities and National Laboratories.

Reviewer 2:
The project goals can be leveraged to support the PACE program.

Reviewer 3:
This project supports the overall DOE objectives by developing improved models and algorithms to enable reliable predictions to support the Co-Optima program.

Reviewer 4:
This project particularly supports DOE goals of development of models and methods for high-performance computing. The knowledge about combustion processes will also be important, and the PIs are encouraged to continually be aware of the other work going on in the Co-Optima and PACE projects as there are a lot of connections that could be made.

Reviewer 5:
Yes, the project is highly relevant, especially in its more accurate sub-models to support different projects. For example, the advanced combustion model would be a good candidate for the cold-start project, etc.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Both financial and personnel resources are sufficient. Computing resources for the project are critical and also sufficient.

Reviewer 2:
Resources are appropriate for a project that is predominantly modeling and simulations.

Reviewer 3:
The project has sufficient resources.

Reviewer 4:
The resources are sufficient at this stage.

Reviewer 5:
The resources are sufficient for this project.

Presentation Number: ace153
Presentation Title: Chemistry of Cold-Start Emissions and Impact of Emissions Control
Principal Investigator: Melanie Moses-DeBusk (Oak Ridge National Laboratory)

Presenter

Melanie Moses DeBusk, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

All reviewers indicated that the project was relevant to current DOE objectives. All reviewers also indicated that the resources were sufficient.

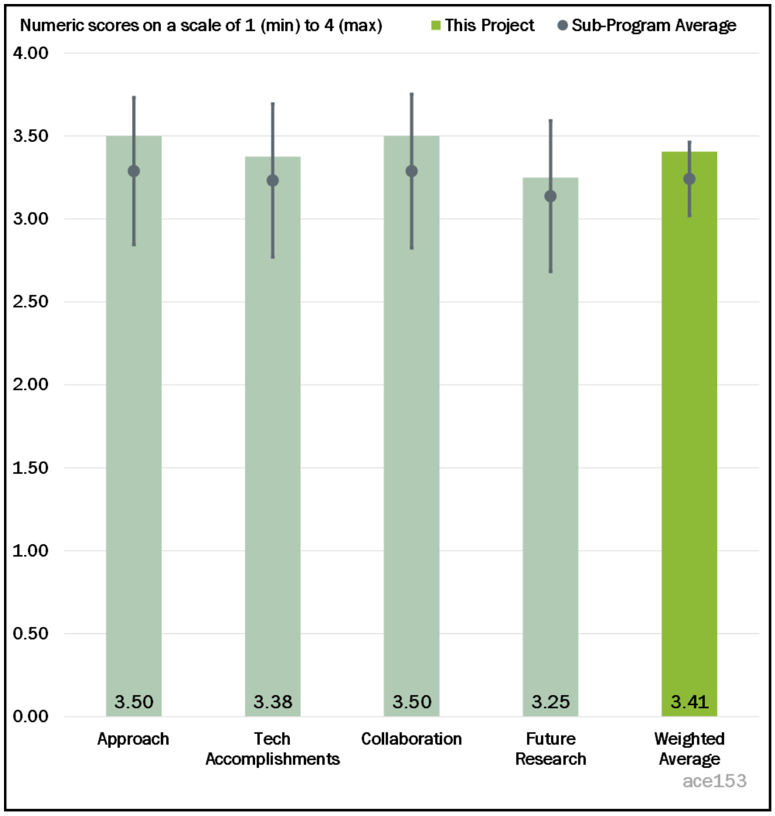

Figure 1-37 - Presentation Number: ace153 Presentation Title: Chemistry of Cold-Start Emissions and Impact of Emissions Control Principal Investigator: Melanie Moses-DeBusk (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The research plan is carefully designed and systematically executed.

Reviewer 2:

This project is well designed and doing a good job of speciating cold-start HC (and particulate) emissions from two late model pick-ups.

Reviewer 3:

The approach is good that HC speciation is explored and analyzed in multiple ways. It would be interesting to see how catalyst companies design the HC trap based on this understanding. Further, as tailpipe emissions regulations are becoming stringent, it is really important to understand details of exhaust and tailpipe emissions.

Reviewer 4:

The project specifically addresses the following barrier identified in the U.S. DRIVE Roadmap: “Similar to design of HC Traps for gasoline exhaust temperature ranges, HC Traps must be designed for effective control of specific HC species that are present in gasoline engine exhaust.” The reviewer’s impression is that the overarching goal of the project is to measure engine-out HC speciation, TWC-out speciation, and HC-trap out speciation. While these will be useful data, it would be good to know how these data are to be used. That is, will the speciation data be used to design HC traps? Will there be any modeling efforts?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The team reported on the laborious work of collecting and analyzing the emission molecules (especially HCs) from the critical first 250 s during typical engine cold start on representative vehicle platforms. The analyses are rigorous and are well supported by abundant data.

Reviewer 2:
Overall progress appears to be on track to meet the stated timeline.

Reviewer 3:
The project is up to schedule and delivered the results with satisfaction. It would be beneficial if particle number (PN) also would be categorized by PN size.

Reviewer 4:
Detailed cold-start hydrocarbon speciation has been completed on two pick-ups from an engine-out location and after the close-coupled catalysts.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer remarked that there is good collaboration with the Ford and Umicore partners on this project.

Reviewer 2:
ORNL and Umicore teams seem to be well coordinated for this project, with the consultation support from Ford and others.

Reviewer 3:
Collaborations between National Laboratories and industry are shown to be effective.

Reviewer 4:
The project appears to be coordinated well across the various participants, although the bulk of the work is being done by ORNL. Regarding the collaboration with the CLEERS community for sharing of results, is there any plan to share the collected data (or a subset thereof) through the CLEERS database? This type of data is difficult to find outside of industry.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Future research is planned for GPF impact on the cold-start emissions. Approach and work content are good.

Reviewer 2:
The project will logically next look at cold-start HC speciation changes after the addition of an underfloor HC adsorber and an underfloor HC adsorber plus GPF. The project will also complete cold-start and re-start HC speciation for a hybrid vehicle application. It would be interesting to see how re-starting HC speciation may change with the time between re-starts in a hybrid vehicle. It also appears that HC adsorber studies will include engine aging of the HC adsorber using the U.S. DRIVE storage aging protocol (50 hour [h]) cyclic aging at 700°C). It would be interesting to speciate HCs post-trap after 25 h and then 50 h of aging to characterize aging impacts on the HC adsorber function.

Reviewer 3:
The proposed future work is sensible and addresses several barriers, including the "rolling cold start" challenge with hybrid vehicles. If there are any decision points (Go/No-Go decisions) or alternate development pathways considered, they are not apparent in the presentation.

Reviewer 4:
Considering the data availability to the public and conclusion applicability to the U.S. automotive industry as a whole, the team needs to go beyond the demonstration of successful data collection (the work can be done by OEMs) by looking into the collected data from the chemistry perspective of how these emission characteristics evolve with vehicle propulsion systems, mileage, and aftertreatment system designs. Such more insightful knowledge as a know-how database can ultimately help the design of more advanced ACE systems, which also echoes the title of the project.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project directly supports the VTO mission to develop cost effective aftertreatment technologies that further reduce emissions.

Reviewer 2:
This project will add important understanding to the development of HC adsorber technology.

Reviewer 3:
It is important to understand the details of emissions from engines and the role of various components. Most of the studies focused on NO_x and PM, but this study is complementary and provides much refined details about HCs and PN.

Reviewer 4:
Having a thorough understanding of the specific chemistry for most of (if not all) the HCs species emitted during the cold start is pivotal in enabling targeted development of catalytic materials and systems to handle the emissions.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This project appears to have sufficient resources to complete the studies planned with HC adsorbers on the selected pick-ups and to characterize cold-start and re-start HC emissions from a hybrid vehicle.

Reviewer 2:
Sufficient resources were contributed by DOE for this work.

Reviewer 3:
Resources for this project appear to be sufficient.

Reviewer 4:
The project coordinates the resources to ensure the completion of the project very well on the hardware side. As suggested, the know-how chemistry should be emphasized by the completion of the project.

Presentation Number: ace154
Presentation Title: Heavy-Duty Hybrid Diesel Engine with Front-End Accessory Drive-Integrated Energy Storage
Principal Investigator: Chad Koci (Caterpillar)

Presenter

Chad Koci, Caterpillar

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 20% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

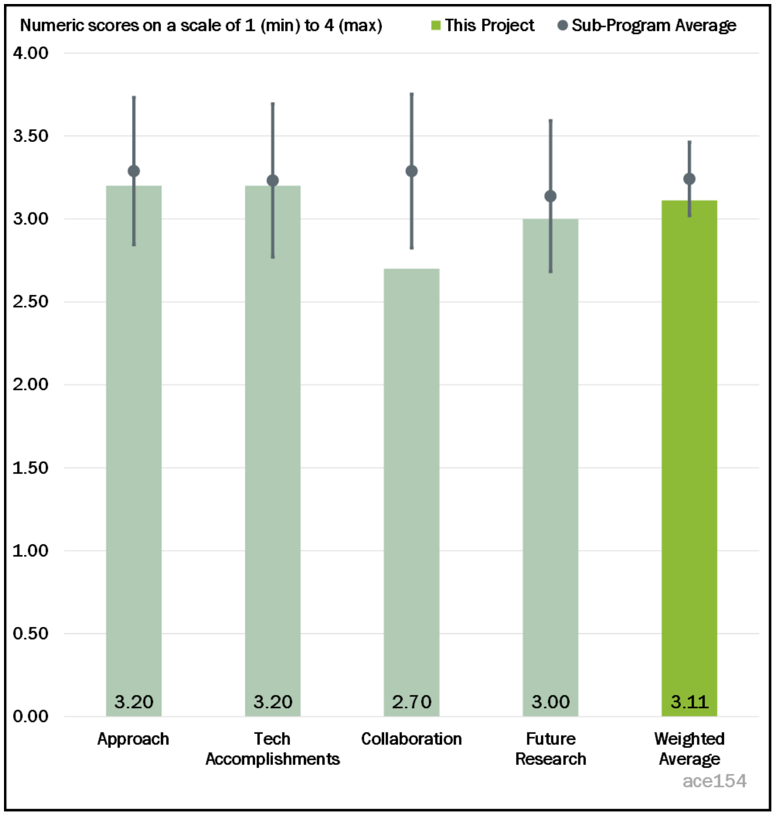

Figure 1-38 - Presentation Number: ace154 Presentation Title: Heavy-Duty Hybrid Diesel Engine with Front-End Accessory Drive-Integrated Energy Storage Principal Investigator: Chad Koci (Caterpillar)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach is very good. The analysis, which led to the identification of how best to apply hybridization, was well done and resulted in identifying the approach that is being taken—hybridized front-end accessory drive (FEAD). It appears to be a very good example of analysis-led design.

Reviewer 2:

The project approach is rather complete, encompassing air handing systems to meet engine downsizing targets, waste heat recovery, parasitic loss reduction, and hybrid powertrain integration. Overall performance targets are clear: 17% percent improved fuel efficiency and reduction of cost of ownership.

Reviewer 3:

The project has sharpened its focus and resources to develop the heavy-duty hybrid diesel (H2D2) for the off-road application. The project has a good systematic approach of using technologies to increase the power-system efficiency through engine downsizing and integration of hybrid front-end accessory drive, including high-speed flywheel (HSFW), turbocharger, and motor-generator unit (MGU). It is clear that a very good integration of many technologies shows promise for significant reduction in fuel consumption while this requires very careful matching of the operating characteristics of each component of the multiple technologies being implemented. The approach being followed here is a systematic and fundamentally based. Given that, the reviewer would have liked to see the data that led to the technical decisions, especially for the thermo-fluid/simulations and waste heat recovery methods. For example, the reviewer questioned the air delivery system improvement of 30% improved power density, and inquired about the specific engine combustion technology adopted to maintain the same level of durability shown in the reference engine.

Reviewer 4:
The analysis-led design approach being implemented in this project, which heavily leverages analytical tools in the early phase if the program is to select and validate system architecture decisions, is fundamentally sound. However, some of the architecture selections, like the use of turbo-compounding as well as the use of both flywheel and motor generator unit, are puzzling since they introduce more complexity than is required.

Reviewer 5:
It was not clear to the reviewer what the distinction is between research and the normal engine development work that Caterpillar does anyway.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The simulation results have shown some encouraging outcomes that have supported the Go/No-Go decisions for the selected architecture.

Reviewer 2:
The project is on task relative to the statement of work (SOW) schedule. The postponement of the first Go/No-Go decision was to enable some additional analysis to be performed and is not affecting the progress of the project. The hybridization system has been identified, along with its components and the logic for its operation. The downsized engine has been identified, and the team is proceeding with set-up and testing.

Reviewer 3:
There has been good progress as the project completes its first year. Some of the reported delays were explained in regard to the overall concept selection and optimization. No delay was reported on the Go/No-Go decision. The presentation makes a good case for the importance of the supervisor-manager and explains the challenges of providing power through the base engine (now download) and from the hybrid and the SuperTurbo power plant. Power system predictions are also included and broken down by category.

Reviewer 4:
In the first year of the project, key items were identified to develop the high-efficiency power system and complete the individual component analysis. It seems the Phase 1 engine was built, and therefore, the project has made significant progress that largely exceeds expectations. However, the reviewer would have liked to see the detailed breakdown of the fuel efficiency table on Slide 12 compared to the cost and performance achievements. The reviewer also would have liked to see results from the thermo-fluid, structure, and dynamic simulations in order to address the air handling requirement in the power system. In the presentation, it is not clear how to increase the efficiency over start/stop implementation.

Reviewer 5:
It was not clear to the reviewer what the distinction is between research and the normal engine development work that Caterpillar does anyway. For example, the reviewer could not figure out if the downsized concept engine was already in development before the project started, but it was shown as an accomplishment. In addition, the reviewer assumed most components put together in the projects are developed by suppliers.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Reasonable levels of collaboration and coordination have been demonstrated between Caterpillar, SuperTurbo Technologies, the University of Texas at Austin, and some vendors.

Reviewer 2:
There appears to be strong collaboration between Caterpillar and the suppliers and DOE.

Reviewer 3:
Work by project partners is indicated throughout the presentation.

Reviewer 4:
The collaboration level seems to be adequate but requires more data exchange and feedback among the academic and industry partners. In particular, the work from the University of Texas at Austin is not well defined.

Reviewer 5:
The reviewer did not see anything here about the collaborative work between parts. For example, what was the role of the University of Texas at Austin?

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The work is well outlined. The work will be taking place in the main subsystems and hybrid integration.

Reviewer 2:
With the analysis done and build-up underway, future work has been clearly identified. The team looks to be on track for their December Go/No-Go decision on proceeding with durability testing.

Reviewer 3:
The future plans are to continue working on the extension of the Phase 1 concept demonstrator engine-only testing and major subsystem analysis. In general, the project's work continues to design the high-efficiency power system through the downsized engine development. In particular, the durability of the downsized engine will be challenging because of the 30% increased power density.

Reviewer 4:
What the reviewer saw from future work is just normal engine development work.

Reviewer 5:
The proposed future research has effectively planned the appropriate tasks and decision points to achieve the project objectives. However, alternate development pathways to mitigate durability concerns as a result of increased power density (cylinder head structural integrity, bearings, crankshaft, etc.) have not been clearly identified. This H2D2 engine is being designed for Caterpillar's wheel loader, excavator, and articulated dump truck. Hybrid systems are usually designed for a given duty cycle. What application duty cycle is being selected for this architecture design? The PIs should consider whether the selected application duty cycle will create a challenge for a different application duty cycle.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Yes, this project supports the overall DOE objectives because it plans to deliver a more fuel-efficient power solution that will have a substantial impact in reducing the total cost of ownership for off-road applications than current Tier 4 diesel engines.

Reviewer 2:
The project seems to be well aligned with DOE objectives by focusing on high-capability air handling equipment and waste heat recovery and reduction in fuel consumption.

Reviewer 3:
It appeared to the reviewer that overall work is relevant.

Reviewer 4:
Heavy-duty, off-road equipment is a critical aspect of our infrastructure and economic well-being. It is also a non-trivial consumer of hydrocarbon fuels, and it is likely to be dependent on IC engines fueled with liquid energy carriers for decades to come. Reducing its CO_2 footprint is important.

Reviewer 5:
Is there any engine development work not in line with DOE objectives of higher efficiency, lower emissions, low cost, and better reliability?

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project is 35% complete and on plan with the current funding level.

Reviewer 2:
It appears that the project is progress on schedule with the current resources.

Reviewer 3:
Resources appear adequate.

Reviewer 4:
The resource appears to be sufficient.

Reviewer 5:
It was not clear to the reviewer why this project received so much DOE funding compared with funds received by National Laboratories and academia for more important work and better results. Is all the work developed by National Laboratories and academia benefiting all industry partners?

Presentation Number: ace155
Presentation Title: Low-Mass and High-Efficiency Engine for Medium-Duty Truck Applications
Principal Investigator: Qigui Wang (General Motors)

Presenter

Qigui Wang, General Motors

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

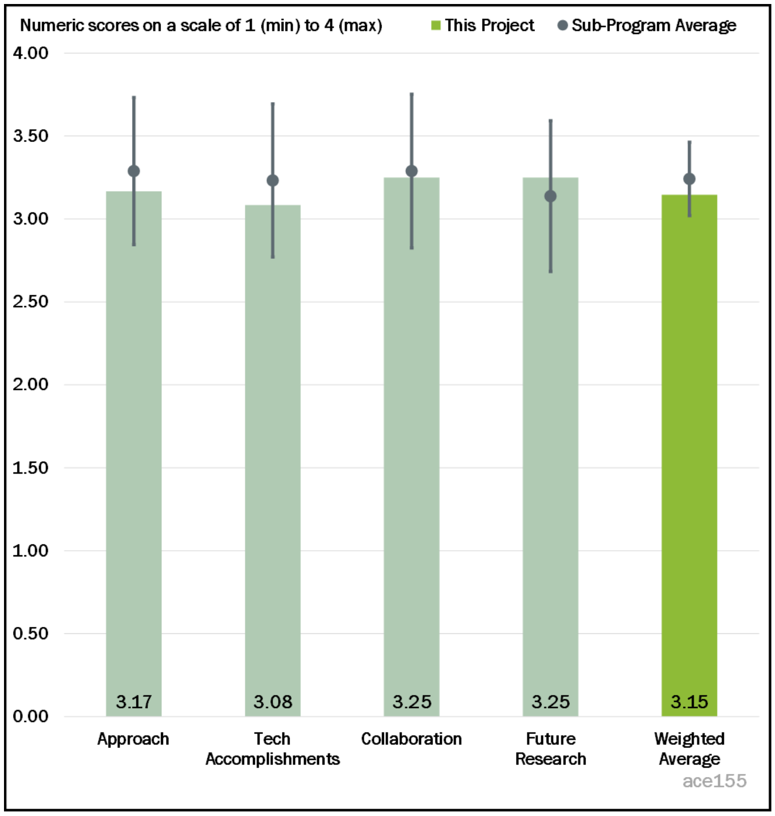

Figure 1-39 - Presentation Number: ace155 Presentation Title: Low-Mass and High-Efficiency Engine for Medium-Duty Truck Applications Principal Investigator: Qigui Wang (General Motors)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

It is good to see that previous DOE program accomplishments are able to contribute to this new project, particularly the propulsion materials and lightweight materials projects referenced.

Reviewer 2:

The reviewer appreciated the team looking at two engine configurations in the first phase of this project. The approach seems appropriate for the technical objectives.

Reviewer 3:

The approach is comprehensive. The use of two new engine configurations at the early stage and then relying on an analytical approach to down-select the engine are technically sound approaches. It would be interesting to see in the next annual report how the integrated computational materials engineering (ICME) approach would be applied in order to accelerate development, reduce risk, and enable tailored properties that lead to cost effective mass reduction.

Reviewer 4:

The project is in its beginning stage. Targets are clearly identified. The project captures two phases (four tasks), encompassing research and development, followed by validation and demonstration. New combustion technologies are outlined. Advanced materials and manufacturing technologies are outlined.

Reviewer 5:
The approach is generally good, but there is not enough definition on the exact approach to give a very solid review. The reviewer chalked that up to this being a pretty new project and looks forward to the next update.

Reviewer 6:
Although very early in the project, already known barriers and challenges were not highlighted much. For example, initial crankshaft analysis demonstrated strength improvement but little weight saving. Peak cylinder pressures need to go up by roughly 50%, but block and head strengths are going to need much more work. Comparing naturally aspirated versus boosted engine designs is a very good thing. Combustion challenges to meet the efficiency target are formidable—even more so with the weight reduction target. The reviewer realized that this is very early in a 4-year project and many big problems have to be solved. The reviewer was just looking for a bit more on the size of the challenge and potential barriers.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
There has been some evident progress in the studies of materials changes to save weight. It is difficult to quantify exactly how fast things should move during a project startup. The reviewer hoped that in the next meeting we can get a better evaluation of the technology development for the combustion system and materials development.

Reviewer 2:
The project is too new to provide much feedback on accomplishments. Ensuring it will fit in the vehicle and projecting the potential weight savings did show significant progress.

Reviewer 3:
The project has just started, so there is not much in the way of accomplishments. The team seems to have a solid plan and is making progress on early requirement setting and research of materials.

Reviewer 4:
The reviewer referenced prior comments and indicated that the project team appears to have a good start and a feasible plan, but wanted a bit more relative to the challenges and barriers.

Reviewer 5:
Good progress has been made in layout and performance simulation of engine architectures, and weight reduction is also moving forward, too. It would be interesting to see whether the cast aluminum engine block can be realized in the next annual report, which can significantly reduce the engine weight. What is Phase 2 Greenhouse Gas Emissions Model (GEM)? Would that be the EPA Phase 2 GEM, which is a vehicle model?

Reviewer 6:
Technology accomplishments included layout and performance simulation of the engine architecture (sweeping engine size parameters—not identified nor ranges identified) via Phase 2 GEM. The baseline was done with the 2015 GM MD truck engine. Some one-dimensional (1-D) engine performance simulations were shown. The physical engine layout of the cab was presented. Mass reduction opportunities are shown, with correlation to the impact to the particular components. Key components, such as block and crankshaft, are included.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The team member responsibilities appear to be well defined.

Reviewer 2:
Work by project partners is indicated throughout the presentation.

Reviewer 3:
It seems that all partners have contributed to the program.

Reviewer 4:
There is a nicely organized team with university, supplier, and National Laboratory partners. In future years, please be sure to indicate the specific accomplishments that each contributed.

Reviewer 5:
Universities and ECK Industries Inc. seem to have their teams identified and work documented. Is there any chance any customer groups can be added in an advisory mode, such as commercial truck fleets or municipal customers? The reviewer believed this would be very beneficial and likely one or more of those groups would be happy and even honored to participate.

Reviewer 6:
It is not obvious that any work has been done at the outside partners yet. There is a list of collaborators with some defined tasks, but it is hard to see what is being done across the team. The reviewer would have liked to see more explanation of how the work split has been accomplished.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future work is very well defined.

Reviewer 2:
The work plan is good, and the reviewer was confident that it will result in a project success. Once there is more concrete definition of the path forward, it will be easier to evaluate the work plan against the distance to the target.

Reviewer 3:
Future work as outlined in the presentation is logical. More detailed internal project plans should highlight barriers and potential alternatives as soon as feasible to identify potential changes to the technology path.

Reviewer 4:
The work is well outlined and will be taking place in the main subsystems. Some consideration is being given to cost-effectiveness (this is tough as no criteria are given), and a little more detail on the down-selection could be given.

Reviewer 5:
The remainder of FY 2020 and FY 2021 research plans look good, although it is not really clear what the criteria for technology down-selection going into phase 2 will be based on if both meet the FOA minimum targets.

Reviewer 6:
A high level was presented, but on only one slide. The reviewer wished that the team had given more detail on the work planned as the project is in such an early stage and is a relatively big project ($10 million). This should be a bigger part of what is presented at an AMR.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project meets the DOE mission of reduced energy consumption and will contribute to the energy security of the United States.

Reviewer 2:
The reviewer believed this project does support the DOE objectives of improving emission and weight in the 3500-truck class of vehicle.

Reviewer 3:
Higher efficiency SI engines for medium-duty applications are a huge potential environmental benefit; this is a well-placed program.

Reviewer 4:
This project supports the overall DOE objectives because of 10% fuel efficiency improvement.

Reviewer 5:
Overall, the work is relevant.

Reviewer 6:
The trucks that this engine will go into will have high volumes and are second to Class 8 tractors in their impact on U.S. emissions and petroleum use.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The budget and spend rate look fine.

Reviewer 2:
Resources appear adequate.

Reviewer 3:
The reviewer stated that the project team has all it needs to complete the program.

Reviewer 4:
At this point in a very new project, there appear to be sufficient resources to reach the stated milestones and they are appropriately challenging.

Reviewer 5:
The reviewer remarked that it is too early in the project to evaluate.

Reviewer 6:
The reviewer commented that it is difficult to tell. The reviewer will assume yes, but no evidence or even a comment to such is in the package or mentioned in the review.

Presentation Number: ace156
Presentation Title: Next-Generation, High-Efficiency Boosted Engine Development
Principal Investigator: Michael Shelby (Ford)

Presenter

Michael Shelby, Ford

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers indicated that the resources were sufficient, 20% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

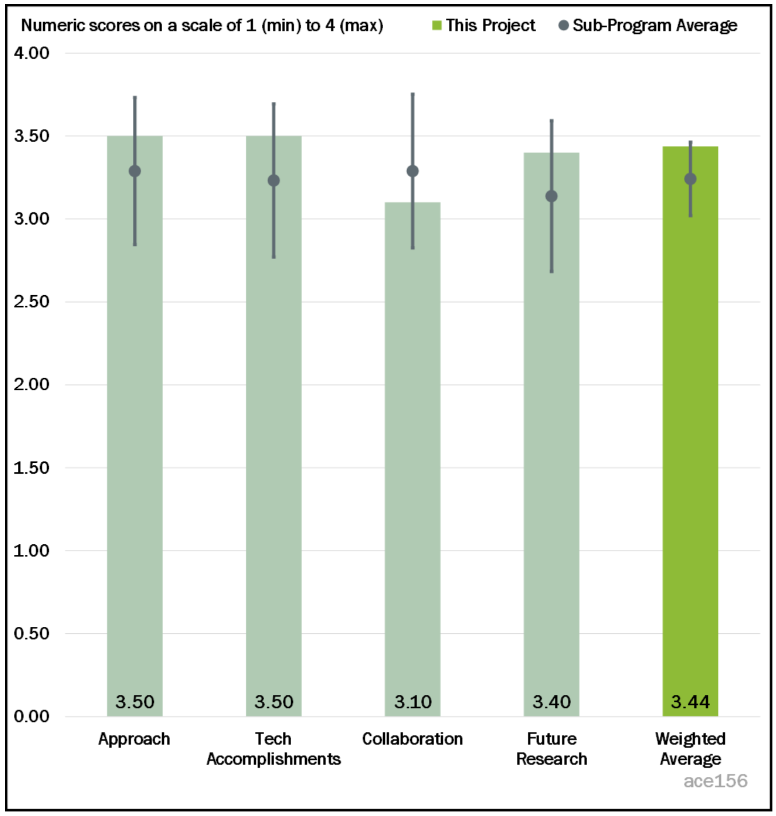

Figure 1-40 - Presentation Number: ace156 Presentation Title: Next-Generation, High-Efficiency Boosted Engine Development Principal Investigator: Michael Shelby (Ford)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Although this project has already selected the engine, the approach is quickly working on detailed technologies to deliver on the objectives.

Reviewer 2:

The approach looks solid with an initial single-cylinder engine, moving to multi-cylinder engine, and then moving to vehicle level. Extensive modeling and analysis will be key to the success of this project to meet its aggressive goals, which far exceed the minimum FOA requirements (23% fuel economy improvement versus 10%).

Reviewer 3:

The technical barriers to completing the work were clearly articulated as well as the approach to address those items. The project appears to be feasible relative to the fuel economy goal, but meeting the weight saving goal would appear to be very difficult given the plans laid out, even with the deletions of components outlined. Just reaching the fuel economy goal is a very formidable challenge.

Reviewer 4:

It would be helpful to provide more description of the approach taken in this project. One slide to summarize the entire approach is too simplified. Also, it would be helpful to add more description of the approach on how the weight reduction goal can be achieved.

Reviewer 5:
The project is really tightly focused on addressing the project goals of mass reduction and engine efficiency improvement. All of the technologies identified appear to be a stretch from where we are today for production applications, but none appears to require a yet-undiscovered solution to be able to be brought to near-production.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
A nice level of detail is provided here, and there is really good progress for the project being at such an early stage. This significant progress seems to have been enabled by the extensive modeling effort (1D and 3D).

Reviewer 2:
For being 6 months in, a lot appears to have been accomplished in terms of nailing down hardware paths and starting to build up test facilities to support the development. These accomplishments gave the reviewer the confidence that there will be ample time for development before the multi-cylinder engine builds need to start.

Reviewer 3:
The project appears to be on schedule, but the milestones for 2020 listed were a little sparse. Analysis work was mentioned (e.g., 14:1 compression ratio [CR]) but does not really appear on the milestones chart until later. Perhaps that is too much detail for a 30-minute report.

Reviewer 4:
The team has obviously jumped on the opportunities having already spent 15% of the program budget. The accomplishments are broad, and many are giving multiple technology opportunities to meet the objectives.

Reviewer 5:
Much progress has been made during the first few months of the project, including compression ratio evaluation, combustion system, and low heat capacity coating. However, progress on the weight reduction is lacking, perhaps due to the early stage of the project. It would be hoped that more progress in weight reduction can be seen in the next annual review.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
It seems that both of the two key partners have contributed to the progress of this work.

Reviewer 2:
The reviewer expected the collaboration to be quite good, given the definition of the partner tasks. It looks like there has not been a ton of joint work to date, but the tasks that involve the partnerships are starting up so we should see a lot more as we go toward the next review.

Reviewer 3:
This looks like a strong team, with a significant dependence on FEV to provide solutions in many key engine design areas. In future AMR presentations, please be sure to specifically call out which team member and accomplishment is attributed to. A university partner would be nice to have on the team, particularly in the three-dimensional (3-D) modeling work, considering the complexity of modeling the pre-chamber.

Reviewer 4:
Clearly there is a good deal of coordination going on within Ford. The other partners seem to be just getting started at this time.

Reviewer 5:
FEV and Oak Ridge seem to have their teams identified and work documented. Is there any chance any customer groups can be added in an advisory mode, such as commercial truck fleets or municipal customers? The reviewer believed this would be very beneficial and likely one or more of those groups would be happy and even honored to participate.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
There are well documented future plans to reach design decisions on time.

Reviewer 2:
The path forward looks really interesting; there are lots of technology paths that are under current research in the DOE that will be brought into this project to see how they work in a production-style development program. The milestones are well defined and look achievable.

Reviewer 3:
Appropriate decision points have been set. However, being so early in the project, it is very hard to evaluate how the team will compensate for the inevitable challenges as they present themselves.

Reviewer 4:
What are the criteria for engine concept selection between the three-spark plugs and pre-chamber? Are cost and reliability the determining factors if performance is equivalent?

Reviewer 5:
The proposed future research is defined well on the performance side, but the proposed new technologies on the engine would increase the challenge of meeting the weight reduction goal. This would become even more challenging since the engine platform of this project is based on an existing engine, which has significant limitations on the weight reduction. It would be helpful if the future work can address this outstanding issue.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project directly feeds into the VTO programmatic goals for efficiency improvement.

Reviewer 2:
The reviewer thought that this project is right in line with the DOE objectives.

Reviewer 3:
This engine would be intended for some of the largest volume LD vehicles on the market; achieving the efficiency improvements targeted would have a huge impact on U.S. fuel consumption and CO_2 emissions.

Reviewer 4:
These pickup trucks are second to Class 8 tractors for emissions and U.S. petroleum impacts. Reductions here are key for the climate and U.S. businesses.

Reviewer 5:
This project will be able to support the overall DOE objectives if the team can achieve its aggressive fuel economy improvement and weight reduction goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The budget level and spend rate look good relative to the project scope and progress.

Reviewer 2:
Resources appear to be sufficient at this time.

Reviewer 3:
The reviewer said that the project team should have all it needs to complete the program at this time.

Reviewer 4:
There was no mention of resources in the slides or in the review. The reviewer realized that Ford has had ongoing projects for these engines over the years with the DOE, but resource plans should be in a review for projects at this stage.

Reviewer 5:
It is difficult to evaluate at the early stage of the project.

Presentation Number: ace157
Presentation Title: Low-Temperature Gasoline Combustion for High-Efficiency Medium- and Heavy-Duty Engines
Principal Investigator: John Dec (Sandia National Laboratories)

Presenter

John Dec, Sandia National Laboratories

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

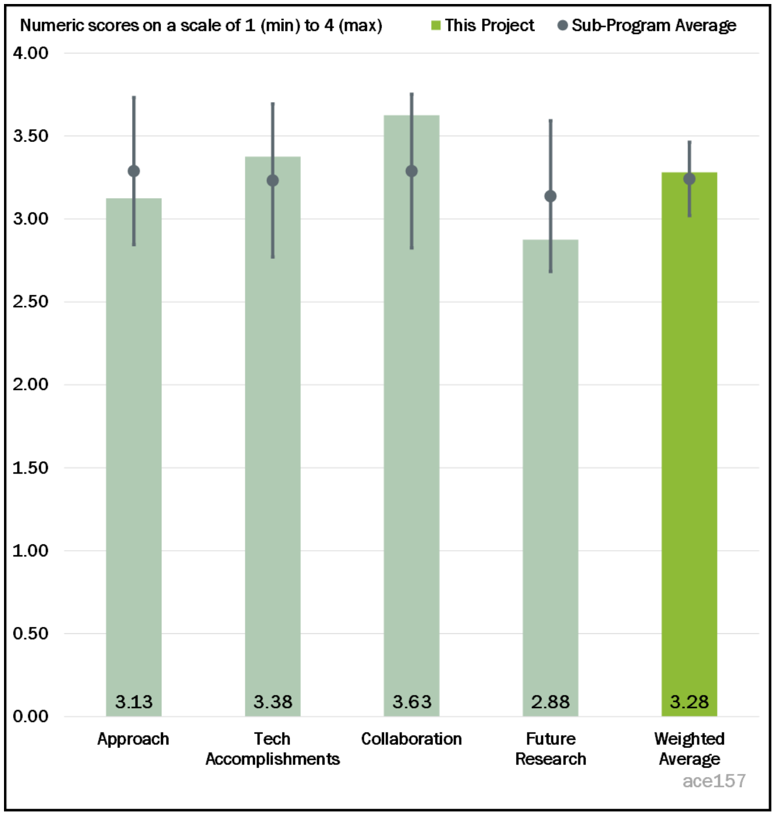

Figure 1-41 - Presentation Number: ace157 Presentation Title: Low-Temperature Gasoline Combustion for High-Efficiency Medium- and Heavy-Duty Engines Principal Investigator: John Dec (Sandia National Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach of complementing analysis with experiments is fundamentally sound, and the PIs have done a good job in identifying the relevant tasks for achieving the project objectives.

Reviewer 2:

The project has clearly defined objectives, and the research activities are laid out well to progress toward achieving those objectives.

Reviewer 3:

At the detail level, this work is very well designed, planned, and executed. A concern of this reviewer is that to ensure that the results of this work can ultimately address key technical barriers and be impactful is that perhaps a bit more effort to assess the overall feasibility of the additive-mixing fuel injection (AMFI) approach is warranted. Specifically, some effort to assess how well this approach works for what would be expected to be the variation of market fuels in the United States is warranted. It is of no value if this approach is not robust enough to work for a broad range of fuels.

Reviewer 4:

The use of LTC to meet the upcoming efficiency and emissions targets is very sound. However, there is significant uncertainty that an AMFI system will ever be commercially viable (it looks like the OBD problem from hell) and the NO_x numbers that need to be considered are NOT EPA 2010 but rather the ultra-low NO_x proposed regs in California (nominally, 0.02 g/kW-h). The ultra-high efficiencies achieved in these LTC strategies tend to make the exhaust temperatures a challenge for keeping SCR warm. This is an issue that would be good to address in the future. In addition, the efficiency comparisons were made to engines that currently achieve significantly longer durability and reliability targets than automotive engines, which substantially degrade their peak efficiency performance. A better comparison for this research-level efficiency would be the efficiencies reported by the SuperTruck teams, since durability is less of a concern in those projects.

The previous work in phi-sensitivity also indicates that phi-sensitivity is enhanced by elevated pressure. Has there been any attempt to use pressure control at TDC (whether by boost or CR, similar to Miller cycle) to manage ignition characteristics instead of 2-ethylhexyyl nitrate (EHN)?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The results showing that LTGC-AMFI can operate over the entire load-speed map of the EPA Generic 7 L diesel with higher BTE are very encouraging.

Reviewer 2:
The investigators have been able to develop approaches (LTGC-AMFI) to overcome the challenges of reaching the objectives of operating over the entire operating map of the engine. Technically, this is a significant accomplishment. Overall, the progress is very good.

Reviewer 3:
Some slight delays were encountered due to the COVID-19 pandemic, but nonetheless this project is progressing well and on track. A minor question and/or comment from this reviewer is to clearly elucidate if and/or how the project team accounted for operation of all the accessory components in estimating BTE. The BTEs that are being reported are very high; thus, it would help make people confident in the results to understand how accessory components were accounted.

Reviewer 4:
The technical accomplishments are quite impressive. Substantial progress toward the goals has been made. There have been several test matrices run that have highlighted the ability of this combustion system to provide very high efficiency and a very low emissions signature. One thing that would be very useful is a sensitivity study on the EHN dosing since, in a standard configuration, there will be six of these devices that need to operate and all of them need to operate within very tight limits to ensure that each and every cylinder is operating within acceptable limits. Even one of six cylinders operating slightly out of limits will create compliance/OBD problems.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Fantastic collaboration and coordination between two National Laboratories, three industry partners, and three universities.

Reviewer 2:
This project appears to have excellent collaboration and coordination among partners. There are OEMs and suppliers involved, other National Laboratories, and universities. Their efforts appear to be reasonably well coordinated and enhancing of each other.

Reviewer 3:
The project appears to be well connected and engaged with industry, National Laboratories, and universities.

Reviewer 4:
Collaboration is extensive and well coordinated.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The future work plans should facilitate continued successful progress

Reviewer 2:
There is a good list of future tasks being proposed that builds on the accomplishments that have been demonstrated so far in the project. However, there are a couple of open questions that the PIs should address. First, can we reach 0.2 g/horsepower (hp)-h NO_x with low-temperature gasoline combustion without excessive HC and CO emissions compared to traditional diesel? Second, most of the challenges being faced in the industry are at low load NO_x, but the PIs are using EHN, which makes more NO_x.

Reviewer 3:
The proposed future work on the AMFI system is reasonable, although there should be a backup plan due to the significant uncertainty that AMFI will ever be robust enough for technology transfer, not to mention the substantial resistance of customers to carrying three consumable fluids (gasoline, DEF, and EHN). Alternate methods of controlling the reactivity in a more robust manner should be explored.

Reviewer 4:
The proposed future work is logical to progress the combustion approach, but effort may be better if reframed or utilized in other directions. The work ought to be compared to state-of-the-art diesel engines that are in production and compare engine-out emissions levels (especially at low load) relative to a state-of-the-art diesel. This comparison should include HC and CO in addition to the existing focus on NO_x and soot. Related to this, efforts must focus on showing pathways to future emissions compliance, not relative to 2010 emissions levels. Finally, as previously mentioned, an effort to show that the AMFI approach works for a spectrum of fuels would also be beneficial.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project supports the overall DOE objectives because it is exploring combustion system technologies that can achieve high thermal efficiency compared with traditional diesel while limiting emissions.

Reviewer 2:
This project definitely supports the overall DOE objectives of high efficiency, low emissions combustion systems.

Reviewer 3:
This project is aligned with DOE's objectives as it aims to develop a more efficient engine.

Reviewer 4:
The project is explained well in the relevance slide.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Progress is excellent and the resources seem adequate.

Reviewer 2:
The project is 53% complete and on plan with the current funding level, which has been consistent over the past couple of years.

Reviewer 3:
The project resources are sufficient for timely project execution.

Reviewer 4:
The resources appear to be sufficient to maintain progress and timeline.

Acronyms and Abbreviations

1-D	One-dimensional
3-D	Three-dimensional
A/F	Air-fuel ratio
A/F	Amplitude-frequency
ACC	Adaptive cruise control
ACE	Advanced Combustion Engine
ACEC	Advanced Combustion & Emissions Control
ACI	Advanced compression ignition
AEC	Advanced Engine Combustion
AI	Artificial intelligence
Al_2O_3	Aluminum oxide (alumina)
AMFI	Additive-mixing fuel injection
AMR	Annual Merit Review
ANL	Argonne National Laboratory
ARB	Air Resources Board
BEA	Zeolite beta
BMEP	Brake-mean effective pressure
BP	Budget period
BSFC	Brake-specific fuel consumption
CA50	Crank angle at 50% mass fraction burned
CAE	Computer-aided engineering
CARB	California Air Resources Board
CCE	Closed-cycle efficiency
CCV	Closed-crankcase ventilation
Cd	Coefficient of drag
CDC	Change-data capture
CDC	Conventional diesel combustion
CDTI	Clean Diesel Technology, Inc.

Ce	Cerium
CeO_2	Cerium oxide (ceria)
CFD	Computational fluid dynamics
CH_4	Methane
CHT	Conjugate heat transfer
CI	Compression ignition
CLEERS	Crosscut Lean Exhaust Emissions Reduction Simulations
CNG	Compressed natural gas
CO_2	Carbon dioxide
COV	Coefficient of variation
CR	Compression ratio
CRADA	Cooperative research and development agreement
C_{rr}	Coefficient of rolling resistance
Cu	Copper
DEF	Diesel exhaust fluid
DFT	Density functional theory
DISI	Direct-injection spark ignition
DNS	Direct numerical simulations
DOC	Diesel oxidation catalyst
DOE	U.S. Department of Energy
DPF	Diesel particulate filter
DRIFTS	Diffuse reflectance infrared Fourier-transform spectroscopy
E10	10% ethanol content gasoline
ECFM	Extended coherent flame model
ECN	Engine Combustion Network
ECU	Engine control unit
EERE	Energy Efficiency and Renewable Energy
EGR	Exhaust gas recirculation

EHN	2-ethylhexyl nitrate
EPA	U.S. Environmental Protection Agency
FCA	Fiat-Chrysler Automobiles
FE	Fuel economy
FE	Fuel efficiency
Fe	Iron
FEAD	Front-end accessory drive
FOA	Funding opportunity announcement
FTP	Federal Test Procedure
FWC	Four-way catalyst
FY	Fiscal year
g	gram
GCI	Gasoline compression ignition
GCMS	Gas chromatography mass spectroscopy
GDI	Gasoline direct injection
GEM	Greenhouse gas Emissions Model
GHG	Greenhouse gas
GM	General Motors
GPF	Gasoline particulate filter
GPU	Graphics processing unit
GVW	Gross vehicle weight
GVWR	Gross vehicle weight rating
H_2	Hydrogen
H2D2	Heavy-duty hybrid diesel
H_2O	Water
HC	Hydrocarbon
HCCI	Homogeneous charge compression ignition
HCT	Hydrocarbon trap

HD	Heavy-duty
HNCO	Isocyanic acid
HP	Horsepower
HPC	High performance computing
HSFW	High-speed flywheel
HSS	High-strength steel
HTA	Hydrothermally aged
HVAC	Heating, ventilating, and air conditioning
IC	internal combustion
ICE	Internal combustion engine
ICME	Integrated computational materials engineering
ID	Ignition delay
IMEP	Indicated mean effective pressure
IP	Intellectual property
ISFC	Indicated specific fuel consumption
JM	Johnson Matthey
K	Potassium
kW	Kilowatt
L	Liter
LANL	Los Alamos National Laboratory
lb	Pound
LD	Light-duty
LES	Large eddy simulation
LEV III	Low-emission vehicle level III
LLNL	Lawrence Livermore National Laboratory
LSPI	Low-speed pre-ignition
LTC	Low-temperature combustion
LTNA	Low-temperature NO_x adsorber

LTP	Low-temperature plasma
m	Meter
MCCI	Mixing-controlled compression ignition
MGU	Motor-generator unit
MHDV	Medium- and heavy-duty vehicle
Micro-CT	Micro-computed tomography
ML	Machine learning
mm	Millimeter
Mn	Manganese
MON	Motor octane number
MOU	Memorandum of understanding
MY	Model year
N_2O	Nitrous oxide
NACFE	North American Council for Freight Efficiency
NG	Natural gas
NGV	Natural gas vehicle
NH_3	Ammonia
NN	Neural network
NO	Nitric oxide (nitrogen monoxide)
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
NP	Nano-palladium
NREL	National Renewable Energy Laboratory
OBD	On-board diagnostics
OC	Oxidation catalyst
OCE	Open-cycle efficiency
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory

OSC	Oxygen storage capacity/component
P	Phosphorous
PACE	Partnership for Advanced Combustion Engines
PAH	Polycyclic aromatic hydrocarbon
PC	Pre-chamber
PCC	Predictive cruise control
Pd	Palladium
PFI	Port fuel injection
Pi	Principal investigator
PMI	Particulate matter index
PN	Particle number
PNA	Passive NO_x adsorber
PNNL	Pacific Northwest National Laboratory
Pt	Platinum
P-T	Pressure-temperature
Q	Quarter
Q&A	Question and answer
R value	Resistance to heat flow
R&D	Research and development
RANS	Reynolds-averaged Navier-Stokes
RCM	Rapid compression machines
Rh	Rhodium
RMS	Root mean square
RON	Research octane number
s	Second
S	Sulfur
SAC	Single-atom catalyst
SCE	Single-cylinder engine

SCO	Selective catalytic oxidation
SCR	Selective catalytic reduction
SCRF	Selective catalytic reduction on filter
SI	Spark ignition
SNL	Sandia National Laboratories
SOW	Statement of work
Spaci-MS	Spatially resolved capillary inlet - mass spectroscopy
SSZ	Alumina silicate zeolite
ST2	SuperTruck 2
SULEV	Super ultra-low emissions vehicle
SwRI	Southwest Research Institute
T	Temperature
TCO	Total cost of ownership
TDC	Top dead center
Tech	Technical
TJI	Turbulent jet ignition
TWC	Three-way catalyst
U.S. DRIVE	U.S. Driving Research and Innovation for Vehicle efficiency and Energy sustainability
UHC	Unburned hydrocarbons
UPS	United Parcel Service
USCAR	United States Council on Automotive Research
UVA	University of Virginia
V	Volt

2. Batteries R&D

The Vehicle Technologies Office (VTO) has a comprehensive portfolio of early-stage research to enable industry to accelerate the development and widespread use of a variety of promising sustainable transportation technologies. The research pathways focus on fuel diversification, vehicle efficiency, energy storage, and mobility energy productivity that can improve the overall energy efficiency and efficacy of the transportation or mobility system. VTO leverages the unique capabilities and world-class expertise of the National Laboratory system to develop innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures; and energy efficient mobility systems. VTO is uniquely positioned to address early-stage challenges due to strategic public-private research partnerships with industry (e.g., U.S. DRIVE, 21st Century Truck Partnership) that leverage relevant expertise. These partnerships prevent duplication of effort, focus DOE research on critical R&D barriers, and accelerate progress. VTO focuses on research that industry does not have the technical capability to undertake on its own, usually due to a high degree of scientific or technical uncertainty, or that is too far from market realization to merit industry resources.

The Battery Technologies R&D (BAT) subprogram funds research programs with partners in academia, National Laboratories, and industry, focusing on generating knowledge of high-energy and high-power battery materials and battery systems that can support industry to significantly reduce the cost, weight, volume, and charge time of plug-in electric vehicle (PEV) batteries. Advanced Battery Materials Research focuses on early-stage research of new lithium-ion cathode, anode, and electrolyte materials, which currently account for 50%–70% of PEV battery cost. This work will be carried out through competitively selected, cost-shared projects, in addition to research conducted as part of the Lithium Battery Recycling Prize and National Laboratory-led Recycling Center launched in fiscal year 2019. Additionally, the subprogram will continue the Battery500 research consortium, which focuses on developing “beyond lithium-ion” technologies that have the potential to significantly reduce weight, volume, and cost by three times ($80/kWh). New research supports batteries and electrification in large trucks, which may require unique technology based on the charging patterns, daily usage, range, and overall length of vehicle life.

The Advanced Battery Cell R&D effort focuses on early-stage R&D of new battery cell technology that contains new materials and electrodes that can reduce the overall battery cost, weight, and volume while improving energy, life, safety, and fast charging. This activity also supports high-fidelity battery performance, life, fast charging, and safety testing of innovative battery technologies at the National Laboratories and the lithium-ion battery recycling center.

The Behind the Meter Storage (BTMS) effort focuses on innovative solutions capable of mitigating potential grid impacts of PEV high-power charging systems, such as critical materials-free battery energy storage technologies. Solutions in the 1–10 MWh range will support optimal charging system design, eliminate potential grid impacts of high-power PEV charging systems, and lower installation costs and costs to the consumer. Efforts will include research and development of advanced power electronics and controls to assure seamless integration of energy storage, vehicle charging, and behind-the-meter power transmission.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0)*. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 2-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat049	Tailoring Integrated Layered- and Spinel-Electrode Structures for High-Capacity Lithium-Ion Cells	Jason Croy (ANL)	2-9	3.25	3.25	3.38	3.25	**3.27**
bat240	High-Energy Anode Material Development for Lithium-Ion Batteries	Cary Hayner (Sinode Systems/ NanoGraf)	2-13	3.00	2.90	3.40	2.80	**2.98**
bat247	Fast-Charge and Low-Cost Lithium Ion Batteries for Electric Vehicles	Herman Lopez (Zenlabs Energy, Inc./ Envia Systems)	2-18	3.20	3.30	3.20	3.20	**3.25**
bat251	Cathode Materials for Next Generation Lithium-Ion Batteries: Design, Synthesis, and Characterization of Low-Cobalt Cathodes	Jason Croy (ANL)	2-23	3.38	3.25	3.63	3.13	**3.31**
bat252	Cathode Materials for Next Generation Lithium-Ion Batteries: Diagnostic Testing and Evaluation of Low-Cobalt Cathodes	Dan Abraham (ANL)	2-27	3.63	3.38	3.50	3.38	**3.45**
bat253	Cathode Materials for Next Generation Lithium-Ion Batteries: Theory and Modeling of Low-Cobalt Cathodes	Hakim Iddir (ANL)	2-31	3.50	3.50	3.50	3.25	**3.47**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat293	A Closed-Loop Process for End-of-Life Electric Vehicle Lithium-Ion Batteries	Yan Wang (Worcester Polytechnic Institute)	2-35	3.20	3.20	3.40	3.20	**3.23**
bat332	High Electrode-Loading Electric Vehicle Cell	Mohamed Taggougui (24M Technologies)	2-39	3.10	3.20	3.20	3.33	**3.19**
bat355	Development of High-Performance Lithium-Ion Cell Technology for Electric Vehicle Applications	Madhuri Thakur (Farasis Energy)	2-43	3.20	3.20	3.50	3.00	**3.21**
bat356	Lithium-Ion Cell Manufacturing Using Directly Recycled Active Materials	Mike Slater (Farasis Energy)	2-47	3.30	3.00	3.00	3.10	**3.09**
bat357	Thicker Cathode Coatings for Lithium-Ion Electric Vehicle Batteries	Stuart Hellring (PPG Industries)	2-52	3.10	3.30	3.50	3.50	**3.30**
bat359	Status and Challenges of Electrode Materials for High-Energy Cells	Stanley Whittingham (Binghamton University)	2-57	3.50	3.50	3.67	3.50	**3.52**
bat360	Scale-Up Optimization and Characterization of High-Nickel Cathodes	Arumugam Manthiram (University of Texas at Austin)	2-60	3.50	3.50	3.50	3.33	**3.48**
bat361	Understanding Electrode Interface Through Cryogenic Electron Microscopy	Yi Cui (Stanford University/ SLAC)	2-63	3.67	3.50	3.83	3.50	**3.58**
bat362	Lithium-Metal Anodes: Problems and Multiple Solutions Based on Hosts, Interphase, and Electrolytes	Jason Zhang (PNNL)	2-66	3.50	3.67	3.67	3.33	**3.58**
bat364	Surface Coating for High-Energy Cathode	Jihui Yang (University of Washington)	2-69	3.17	2.83	3.33	3.00	**3.00**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat365	Stabilizing Lithium-Metal Anode by Interfacial Layer	Zhenan Bao (Stanford University/ SLAC)	2-72	3.20	3.40	3.50	3.20	**3.34**
bat366	Advanced Imaging and Quantitative Characterization of Lithium-Metal Anode and Its Solid Electrolyte Interphase (SEI)	Shirley Meng (University of California at San Diego)	2-77	3.50	3.67	3.67	3.17	**3.56**
bat367	Characterization Studies on Li-Metal Anode and High-Ni Cathode Materials	Peter Khalifah (BNL)	2-80	3.50	3.50	3.50	3.50	**3.50**
bat368	Battery500 Integrated Cell Diagnostics and Modeling to Identify Critical Gaps in Achieving High Cycle Life	Eric Dufek (INL)	2-82	3.17	3.33	3.83	3.17	**3.33**
bat369	High-Energy Rechargeable Lithium-Metal Cells: Fabrication and Integration	Jie Xiao (PNNL)	2-85	3.70	3.60	3.50	3.20	**3.56**
bat370	Advanced Diagnostics of Nickel-Rich, Layered-Oxide Secondary Particles	Mike Toney (Stanford University/ SLAC)	2-89	3.50	3.60	3.40	3.50	**3.54**
bat376	Disordered Rocksalt Transition-Metal Oxides (TMOs): Recent Advances	Gerbrand Ceder (LBNL)	2-93	3.50	3.38	3.50	3.25	**3.41**
bat388	Silicon Deep Dive: Update and Overview	Jack Vaughey (ANL)	2-97	3.50	3.40	3.50	3.20	**3.41**
bat392	Enabling Rapid Charging in Lithium-Ion Batteries via Integrated Acoustofluidics	James Friend (University of California at San Diego)	2-102	3.38	3.13	3.38	3.13	**3.22**
bat393	Development of an Extreme Fast-Charging Battery	Chao-Yang Wang (Penn State University)	2-106	3.38	3.38	3.50	3.25	**3.38**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat394	Highly Ordered Hierarchical Anodes for Extreme Fast-Charging Batteries	Neil Dasgupta (University of Michigan)	2-110	3.25	3.50	3.50	3.13	**3.39**
bat395	Developing Safe, High-Energy, Fast-Charge Batteries for Automobiles	Wenjuan Mattis (Microvast, Inc.)	2-114	3.00	3.00	3.00	3.17	**3.02**
bat396	Enabling Extreme Fast Charging through Anode Modification	Esther Takeuchi (Stony Brook University)	2-117	3.33	3.17	3.33	3.33	**3.25**
bat397	Titanium Niobium Oxide-Based Lithium-Ion Batteries for Extreme Fast-Charging Applications	Sheng Dai (University of Tennessee at Knoxville)	2-120	3.00	2.67	3.17	2.83	**2.83**
bat398	Extreme Fast-Charging Lithium-Ion Batteries	Edward Buiel (Edward Buiel Consulting, LLC)	2-124	2.83	2.67	2.50	3.00	**2.73**
bat400	Novel Liquid/Oligomer Hybrid Electrolyte with High Lithium-Ion Transference Number (Hi-LiT) for Extreme Fast Charging	Zhijia Du (ORNL)	2-127	3.33	3.00	3.33	3.00	**3.13**
bat401	Advanced Electrolytes for Extreme Fast Charging	William Chueh (Stanford University)	2-130	3.33	3.33	3.17	3.17	**3.29**
bat404	Direct Fluorination of Disordered Rock Salt Cathode Oxides : Synthesis and Characterization	Jagit Nanda (ORNL)	2-133	3.50	3.38	3.38	3.25	**3.39**
bat405	Advanced Microscopies of Next-Generation Lithium-Ion Battery Cathode Materials	Chongmin Wang (PNNL)	2-137	3.13	3.25	3.38	3.13	**3.22**
bat406	Disordered Rocksalt Transition-Metal Oxides (TMOs): Synthetic Strategies	Guoying Chen (LBNL)	2-140	3.38	3.25	3.25	3.13	**3.27**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat411	Aerosol Manufacturing Technology for Production of Low-Cobalt Lithium-Ion Battery Cathodes	Toivo Kodas (Cabot Corporation)	2-144	3.00	3.17	3.33	3.17	**3.15**
bat412	Novel Lithium-Iron and Aluminum Nickelate (NFA) as Advanced Cobalt-Free Cathode Materials	Ilias Belharouak (ORNL)	2-147	3.33	3.33	3.33	3.33	**3.33**
bat413	High-Performance, Low-Cobalt Cathode Materials for Lithium-Ion Batteries	Donghai Wang (Penn State University)	2-150	3.00	2.83	3.00	2.50	**2.85**
bat414	Enhancing Oxygen Stability in Low-Cobalt, Layered-Oxide Cathode Materials	Huolin Xin (University of California at Irvine)	2-153	3.63	3.63	3.63	3.38	**3.59**
bat415	High-Nickel Cathode Materials for High-Energy, Long-Life, Low-Cost Lithium-Ion Batteries	Arumugam Manthiram (University of Texas at Austin)	2-157	3.67	3.50	3.50	3.33	**3.52**
bat416	Cobalt-Free Cathode Materials and Their Novel Architectures	Shirley Meng (University of California at San Diego)	2-160	3.50	3.50	3.63	3.25	**3.48**
bat417	Cobalt-Free Cathodes for Next-Generation Lithium-Ion Batteries	Neil Kidner (Nexceris)	2-163	3.00	2.67	2.83	2.83	**2.79**
bat436	Silicon Electrolyte Interface Stabilization (SEISTA): Update and Overview	Tony Burrell (NREL)	2-166	3.50	3.60	3.60	3.10	**3.51**
bat437	Silicon Electrolyte Interface Stabilization (SEISTA): Electrochemical Methods	Robert Kostecki (LBNL)	2-171	3.60	3.30	3.50	3.20	**3.39**
bat438	Silicon Electrolyte Interface Stabilization (SEISTA): Advanced Characterization	Glen Teeter (NREL)	2-175	3.40	3.20	3.50	3.20	**3.29**
bat439	Silicon Deep Dive: Silicon-Based Slurries and Electrodes	Beth Armstrong (ORNL)	2-179	3.70	3.40	3.50	3.20	**3.46**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat440	Silicon Deep Dive: Silicon Functionalization	Zhengcheng Zhang (ANL)	2-183	3.50	3.38	3.50	3.13	**3.39**
bat441	High-Performance Electrolyte for Lithium-Nickel-Manganese Oxide (LNMO)/Lithium-Titanate (LTO) Batteries	Jennifer Hoffman (Gotion)	2-187	3.30	3.00	3.20	3.00	**3.10**
bat442	Behind-the-Meter-Storage (BTMS) Overview	Anthony Burrell (NREL)	2-192	3.00	2.25	3.00	2.00	**2.50**
bat444	Highly Loaded Sulfur Cathode, Coated Separator, and Gel Electrolyte for High-Rate Lithium-Sulfur Battery	Yong Joo (Cornell University)	2-195	3.40	3.20	3.50	3.30	**3.30**
bat445	Multifunctional Lithium-Ion Conducting Interfacial Materials for Lithium-Metal Batteries	Donghai Wang (Penn State University)	2-200	3.50	4.00	3.33	3.50	**3.73**
bat446	Electrochemically Stable, High-Energy Density Lithium-Sulfur Batteries	Prashant Kumta (University of Pittsburgh)	2-203	3.50	3.50	3.50	3.17	**3.46**
bat447	3-D Printed, Low-Tortuosity Garnet Framework for Beyond 500 Wh/kg Batteries	Eric Wachsman (University of Maryland)	2-206	3.17	3.17	3.33	3.33	**3.21**
bat448	Advanced Electrolyte Supporting 500 Wh/kg Lithium-Carbon/Nickel Manganese Cobalt (NMC) Batteries	Chunsheng Wang (University of Maryland)	2-209	3.60	3.80	3.40	3.50	**3.66**
bat449	Controlled Interfacial Phenomena for Extended Battery Life	Perla Balbuena (Texas A&M)	2-214	3.50	3.00	3.33	3.17	**3.19**
bat450	Design, Processing, and Integration of Pouch-Format Cell for High-Energy Lithium-Sulfur Batteries	Mei Cai (General Motors)	2-218	3.67	3.50	3.67	3.67	**3.58**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat451	Solvent-Free and Non-Sintered 500 Wh/kg All Solid-State Battery	Mike Wixom (Navitas Advanced Solutions Group)	2-221	3.17	2.50	3.50	3.33	**2.90**
bat452	High-Energy Solid-State Lithium Batteries with Organic Cathode Materials	Yan Yao (University of Houston)	2-224	3.25	3.13	3.38	3.25	**3.20**
bat453	Composite Cathode Architectures Made by Freeze-Casting for All Solid-State Lithium Batteries	Marca Doeff (LBNL)	2-228	3.50	3.50	3.50	3.50	**3.50**
bat454	Development of Long-Life Lithium/Sulfur-Containing Polyacrylonitrile Cells	Ping Liu (University of California at San Diego)	2-231	3.83	3.50	3.83	3.50	**3.63**
bat455	In Operando Characterization of Lithium Plating and Stripping	William Chueh (Stanford University)	2-235	3.50	3.33	3.50	2.83	**3.33**
Overall Average				**3.36**	**3.29**	**3.41**	**3.20**	**3.31**

Presentation Number: bat049
Presentation Title: Tailoring Integrated Layered- and Spinel-Electrode Structures for High-Capacity Lithium-Ion Cells
Principal Investigator: Jason Croy (Argonne National Laboratory)

Presenter

Jason Croy, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

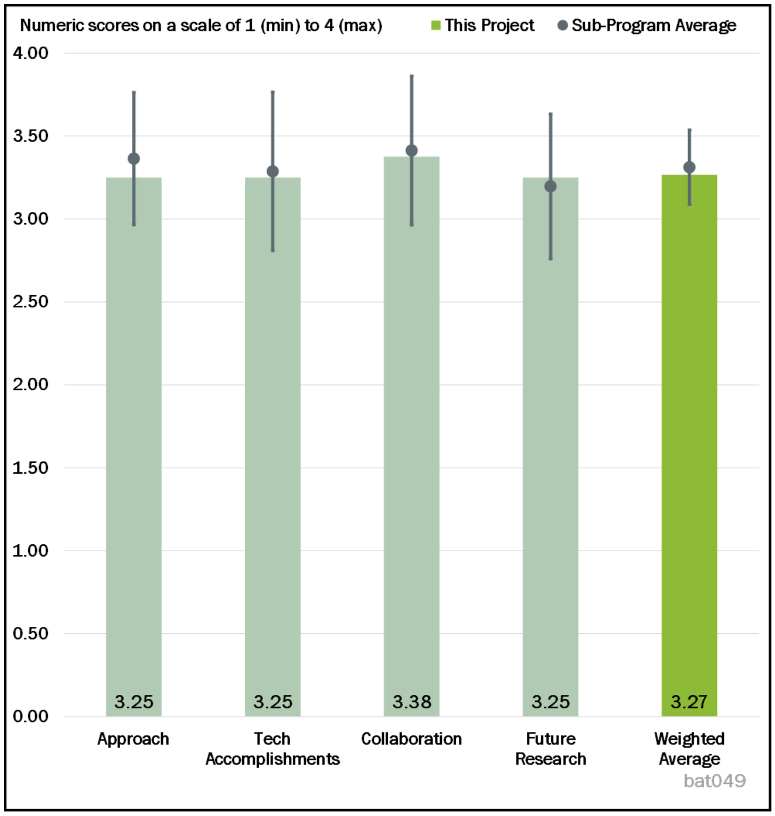

Figure 2-1 - Presentation Number: bat049 Presentation Title: Tailoring Integrated Layered- and Spinel-Electrode Structures for High-Capacity Lithium-Ion Cells Principal Investigator: Jason Croy (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This work showed very promising results with the manganese (Mn)-rich layered-layered-spinel (LLS) cathode. The precipitation parameters were very interesting and resulted in single crystals of manganese carbonate ($MnCO_3$) precursor. It would be interesting if, in the future, those cathode particles show electrochemical advantages versus standard powders. The reviewer found the results presented by the team for cathode powders with no cobalt (Co) content to be very exciting.

Reviewer 2:

There is lot of value in developing better understanding of the relationships between synthesis parameters and cathode particles. Designing robust surfaces also has a potential to address some of the key challenges.

Reviewer 3:

In the last year, the team has identified a critical point to develop the novel layered-layered-spinel lithium (Li), Mn-rich oxides using facile co-precipitation. The idea to use slight adjustments of calcination temperature is a good approach to produce samples with significantly different properties and performance to understand its mechanisms.

Reviewer 4:

Some interesting results are shown, but it was not clear to the reviewer how scientific information from one area is informing the work in another.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
In the last year, the team unraveled the trend of higher calcination temperatures resulting in large primary particles, smaller surface area, limited diffusivity, and less favorable electrochemistry. An atomic-layer deposition (ALD)-coated lithium-fluoride (LiF) layer was used to confirm the improvement of cyclic performance. Also, some preliminary results of morphology control of $MnCO_3$ precursors and low-temperature spinel zero-strain cathodes are interesting findings.

The reviewer recommended two areas for further elaboration and asked why such a narrow range of temperature change (925°-1,000° Celsius [C]) can introduce such a big difference. It would be helpful to provide more supporting data to investigate structural information, such as high-resolution scanning transmission electron microscopy for the long-range and short-range ordering. It would be interesting to know if there is any significant oxygen release in Cycle 1 for the LLS cathode when charging up to 4.6 volts (V). If so, the role of a LiF coating to suppress the gas release can be discussed.

Reviewer 2:
The reviewer commented that the lithiation experiments that resulted in different surface-area powders are very interesting. It could be of interest to see if the higher surface-area powders obtained at lower processing temperatures are better powders for high-power applications. The generation of cubic and rhombohedral structures of cathode material obtained by modifying the Mn concentration is something that can improved in the future. It was not clear to the reviewer how less spherical particles can overcome the lower tap density that those powders will show; in a practical application, the overall capacity of electrodes fabricated using those powders will be decreased. Spherical particles are the particles of choice in practical applications. How can the team bypass that issue?

Reviewer 3:
This project in part focused on the Mn-rich cathode and studied the effect of calcination temperature. Time for calcination was not provided. In fact, one should look at the temperature-time trajectory for each calcination. It was interesting that the team observed an interesting variation in the properties in a narrow temperature range. What are the scientific rationales for the observed behavior?

Reviewer 4:
The reviewer noted that progress was made and useful insight was generated on the impact of synthesis conditions, lithiation, surface treatment, and other approaches on cathode properties.

Some of the observed effects have opposing impacts. For example, higher calcination temperature reduces surface area, but it also seems to negatively impact discharge capacity. It would be useful to clarify if there is a path to optimize synthesis and other conditions in such a way to prevent or minimize tradeoffs. This was not clear from the presentation and work to date.

Small changes to synthesis conditions can result in large changes in properties and performance. This can be a concern for practical application of proposed approaches.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration and coordination among Argonne National Laboratory (ANL), University of Illinois at Chicago, and universities seems to be excellent.

Reviewer 2:
Collaboration seems to be working well. Electron microscopy, X-ray analysis, stability analysis, synthetic efforts, and electrochemical measurements are well coordinated, according to the reviewer.

Reviewer 3:
The team collaboration looks good.

Reviewer 4:
In the last year, the team has indicated the close collaboration within various teams at ANL. The reviewer observed that the external collaboration outside ANL could be considered as well, if needed.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
According to the reviewer, the project team proposed a reasonable plan of next-year actions. It is interesting to see more results of the application of online electrochemical mass spectroscopy (OEMS) and the further scale-up confirmation of low-temperature (LT)-spinel zero-strain cathodes with the electrochemistry incorporated in a solid-state battery cell.

Reviewer 2:
Future experiments probably may need to show some electrochemical data from the cubic and rhombohedral particles. Furthermore, by using dilute Mn solutions during synthesis, the process will generate less cathode material per unit of time. Maybe that can be countered by decreasing the residence time for this precipitation reaction. Maybe residence time is one of the variables that the project team may want to explore. The particle shape or sphericity of the particles is also dictated by the stirring power. That could be an additional precipitation variable that the team may want to explore.

Reviewer 3:
The reviewer said that this is an extension of the current work.

Reviewer 4:
The focus of integrated structures seemed adequate to the reviewer, who commented that designing more robust surfaces and using gas analysis should reveal more details.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Yes, this project supports the overall U.S. Department of Energy (DOE) objectives of decreasing Co content in cathode materials to lower the cost of the battery without decreasing the electrode performance. Experimental data clearly showed the production of such powders with promising electrochemical data.

Reviewer 2:
The reviewer stated that the project supports the overall DOE objectives. This study is focusing on the understanding of a new type of Li-rich cathode having comparable electrochemistry compared to conventional nickel manganese cobalt oxide (NMC) but with lower cost and higher stability. This understanding is favorable for next-generation electric vehicle (EV) applications.

Reviewer 3:
A Mn-rich cathode has the potential provide a cheaper and safer cathode.

Reviewer 4:
This project supports the overall DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This project has achieved the designated milestones on time so far with the sufficient resources.

Reviewer 2:
The team has needed resources in place.

Reviewer 3:
Resources seemed sufficient to the reviewer.

Reviewer 4:
At this stage the resources may be sufficient. However, at some point, the project team may want to scale up the precipitation process. In that case they will need additional support.

Presentation Number: bat240
Presentation Title: High-Energy Anode Material Development for Lithium-Ion Batteries
Principal Investigator: Cary Hayner (NanoGraf)

Presenter

Cary Hayner, NanoGraf

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

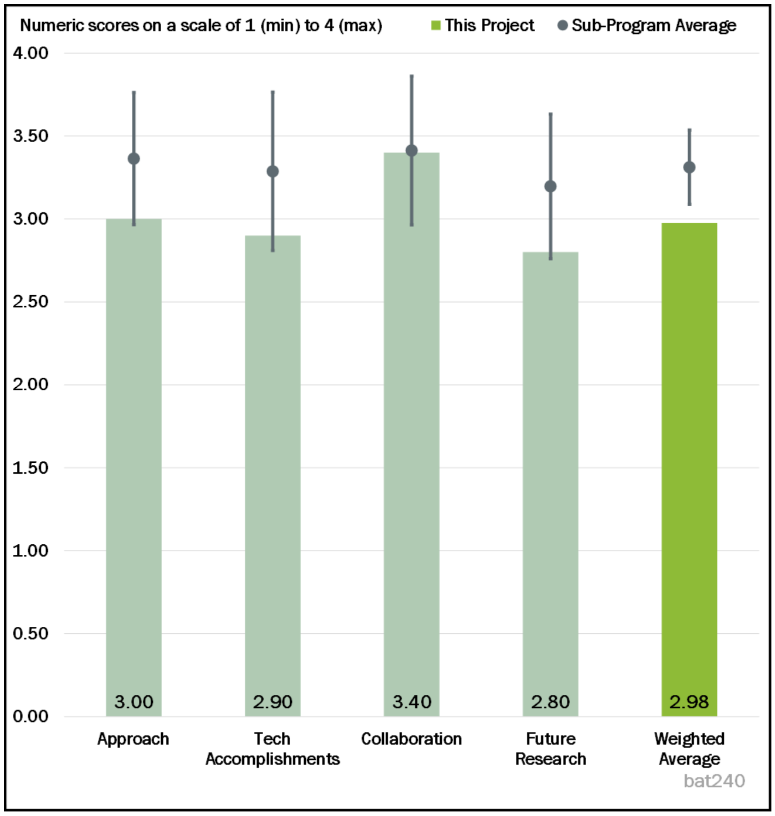

Figure 2-2 - Presentation Number: bat240 Presentation Title: High-Energy Anode Material Development for Lithium-Ion Batteries Principal Investigator: Cary Hayner (NanoGraf)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Researchers addressed the barriers very well by demonstrating increased energy density and specific energy in improving battery life performances. The reviewer also liked the parallel path approach in addressing the battery- life performance issues.

Reviewer 2:

Nanograf is developing high-energy, Si-based anodes for lithium-ion batteries (LIBs). The major approaches include graphenic wrapping and surface coating. While the project was just started last year, the company has made some modest progress. One of the potential issues about the approach is the cost of graphene.

Reviewer 3:

The company’s approach to producing a Si-based material for Li-ion cells is to coat the material with graphene, which is interesting. Its approach to making improvements was not so clear to the reviewer.

Reviewer 4:

For cells using significant amounts of Si, the swelling of the cell must be addressed. This appears to be completely missing from the approach. The reviewer suggested that the project team please measure the reversible volume change during one charge-and-discharge cycle and the irreversible volume change after many cycles. Additionally, the heat generated with respect to the silicon hysteresis could also be important for fast charging. The reviewer asked the team to please measure this contribution.

Reviewer 5:
The project was designed by Nanograf, which is aiming to be a component manufacturer of anode powders, but the barriers being addressed are perhaps better addressed by a battery manufacturer, which Nanograf says they are not interested in becoming. So, as noted in the presentation, Nanograf is trying to accomplish "technology push" and provide the full-cell research and development (surface treatments, electrolyte additives, binders, cell balancing, etc.) to demonstrate the value proposition of their graphene-wrapped Si-anode material.

It was not clear to the reviewer how the project is designed to incorporate the help of A123 in these tasks. For example, is A123 helping with finding new electrolyte additives to form stable solid-electrolyte interphases (SEIs)? Although they probably could use more explicit help from A123, it is clearer how the performance and lifetime barriers are being addressed by Nanograf, but it was not clear how the cost targets are being addressed. There was no goal stated (i.e., a % decrease in cost of what?), and there was only a brief mention that cost is being considered. How are cost factors affecting the optimization of the anode materials to meet technical performance goals? Surely cost is being considered, but it was not clear how the project is specifically designed to achieve cost targets.

Given that performance still has a long way to go to meet the targets and there are clearly many competing factors in the performance, the project could also benefit from a more explicit role for post-mortem testing to determine the failure mechanisms and guide mitigation strategies. Having this type of work just in the background will likely hinder progress eventually.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
A 25% increase in life cycle from the previous year is very good path forward. Researchers also addressed the logistics footprint by improving manufacturing, supply chain, and sourcing for all commercial application; if implemented, this will be very useful.

Reviewer 2:
In quarter (Q) 1 of 2020, the project team achieved a cycle life of 320 with 80% capacity retention for their microstructural, treated graphene-wrapped silicon oxides (SiO_x) material. They also delivered 18, 1-amp-hour (Ah) cells for testing.

Reviewer 3:
The project team showed that it can get 200 cycles with SiO_x and graphene and 300 cycles with a mixture of SiO_x and graphite. Then the team performed a "microstructural treatment" to the SiO_x + graphene and increased the cycles to 288. The reviewer commented that there is no indication of what this is. With continual modifications of microstructural treatment, the team further improved the cycle life and the first-cycle coulombic efficiency (CE). With new surface treatments, the team can improve the first-cycle efficiency (FCE) and the capacity fade, but there was no explanation.

When the wrapping quality of the graphene is good, the results show low resistance of the electrode and good cyclability. With an improved electrolyte formulation, the team increased the cycle life to 350 cycles. Working with PPG, the team discovered a binder that does not require N-methyl-2-pyrrolidone (NMP) and only requires 2 weight percent (wt. %) with good adhesion. Work in material scale-up allows them to produce 80 kilograms (kg) per month and nearly the same capacity retention. These results are good, but there is no information as to how the team is making progress and so it was difficult for the reviewer to see how there will be further progress.

Reviewer 4:
This Si system appears to be at a very low technology readiness level (TRL). It is also not obvious to the reviewer that progress will be made during this project to raise it to a TRL.

Reviewer 5:
The project appears to be making some progress and has produced the first round of test cells for independent testing basically on schedule, but it was less clear to the reviewer that real progress against the performance indicators has been made. The performance improvements seem very incremental and not integrated; that is, FCE is improved in some data, but incremental gains in capacity retention seem to be lost.

Incremental gains in cycle life are achieved, but the materials have FCEs of only 66%. There is still a long way to go to reach 1,000 cycles and FCE of 85% at high energy density, and incremental improvements are not likely to be sufficient to reach the goals in another 2 years.

While the reviewer welcomed improvement in cycle life, the data suggest that there is a serious degradation mechanism limiting performance: the capacity retention generally falls quickly to 90% in the first 40 cycles, and the improvements only slow down the remaining degradation to 80% and incrementally improve cycle life. As suggested in the response to a reviewer's question, the company believes that the loss in capacity is due to Li inventory loss from SEI formation/re-formation, not from loss of electrical connectivity. However, the graphene innovation that the company is promoting is to solve the latter, which does not seem to be the problem.

So, Nanograf seems to be assuming the role of battery manufacturer after all and is trying to solve system-level problems that are general to Si-anode materials and not well addressed by their particular innovation—at least that is how it appears from the materials presented. On the positive side, the introduction of quality control processes and the increase in anode material production are both important improvements.

It was not clear to the reviewer how helpful the increase in peel strength for a cathode binder is for the project. What barrier to Si-anode usage in EVs does that address? Does it maybe address cost?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Working with PPG and A123 helps to eliminate some of the bottlenecks in terms of materials supply and material characterization and also improves the research speed.

Reviewer 2:
Nanograf has involved several other companies with great and unique capabilities.

Reviewer 3:
It looked to the reviewer like close collaboration between project partners.

Reviewer 4:
The company collaborates with A123 and PPG, both industrial companies. Nanograf should be encouraged to find collaborators in National Laboratories and universities for more advanced testing techniques.

Reviewer 5:
The coordination of the effort across the partner set seems to be adequate although it was not clear to the reviewer who will do the safety and abuse testing that is mentioned. Again, collaboration could be better, or at least presented better. How much collaborative help is A123 providing in what appears to have become full-cell optimization, not just anode modification studies?

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
There is a good path forward as the project team has identified a research approach to increase cycle efficiency, active materials, and also several associated variables to enhance further research.

Reviewer 2:
The plan for future research is focused on the right things. As expected, it is likely that the first cells being tested by ANL will show 400 or so cycles. So, the question is where to go to get the necessary improvements? The plan covers the basics and has a couple more decision points for the later test cells. It is not clear what happens if the second set of test cells comes back with only 450 cycles or comes back with the desired 600 cycles but very low FCE.

Is there really going to be a significant effort in looking at different formats: pouch, cylindrical, prismatic? The plan for the future might benefit from thinking now about what to do if it becomes apparent that incremental progress will not get the project to its goals in the remaining project time.

Reviewer 3:
The company's current technology has not yet reached the DOE and U.S. Advanced Battery Consortium (USABC) 2025 goals. They also need to get an assessment of the long-term cost for scale-up manufacturing.

Reviewer 4:
The reviewer noted that future plans are essentially to make everything better.

Reviewer 5:
There is no clear path to reach the project objectives.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is well aligned with DOE objectives by attempting to answer the key questions about whether or not Si anodes are a viable solution for the EV market and are able to compete with graphite on performance and cost targets. Reaching the project goals would go a long way in answering those questions and have significant impact on the DOE objectives for vehicle electrification.

Reviewer 2:
The reviewer stated that the proposed research fits the DOE objectives and mission needs.

Reviewer 3:
A Si-based anode for LIBs is currently a major focus for achieving the targeted battery performance for electric vehicles.

Reviewer 4:
This supports DOE's objectives of improving the energy density of cells to reduce cost and extend range.

Reviewer 5:
High amounts of Si are unlikely to simultaneously achieve DOE's goal of low cost and fast-charge capability.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
At this point in the project, the resources available to the project appear to be sufficient to complete the research and development plan as proposed. There is no guarantee that the final milestones will be achieved, but the project has not suffered any costly setbacks yet that would make reaching the goals impossible. Cost and schedule for the project seem to be on track at the one-third point in the project.

Reviewer 2:
The researchers have sufficient and necessary resources to carry out the research.

Reviewer 3:
The project team is doing well in keeping track on their milestones.

Reviewer 4:
The resources are reasonable.

Reviewer 5:
The resources are sufficient.

Presentation Number: bat247
Presentation Title: Fast-Charge and Low-Cost Lithium Ion Batteries for Electric Vehicles
Principal Investigator: Herman Lopez (Zenlabs Energy)

Presenter

Herman Lopez, Zenlabs Energy

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

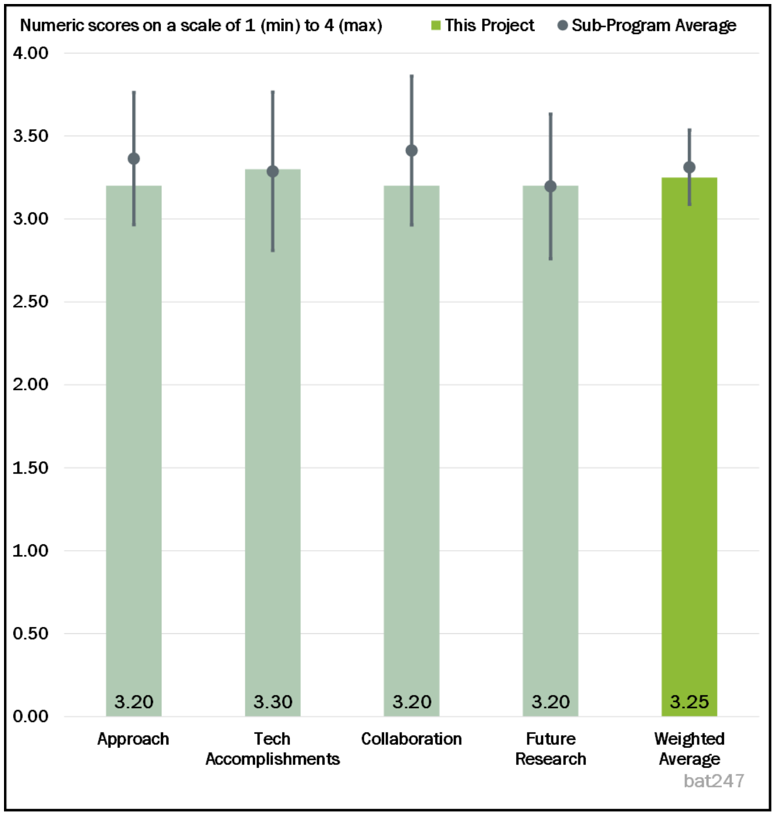

Figure 2-3 - Presentation Number: bat247 Presentation Title: Fast-Charge and Low-Cost Lithium Ion Batteries for Electric Vehicles Principal Investigator: Herman Lopez (Zenlabs Energy)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Researchers have developed a nice flow chart on the cell development strategy and clearly identified upfront the barriers for fast-charge performance, which were addressed sufficiently.

Reviewer 2:

The project is very well planned and comprehensive and is clearly focused strongly on the technical barriers for fast charge and cycle/calendar life. While it can be assumed that the team is addressing the cost barriers in its work to evaluate and downselect electrolyte additives, solvents, salts and various electrode materials, it was not clear from the poster how the USABC 2023 cost targets are being addressed. It would have been helpful to the reviewer to have some idea how much cost reduction (%) was being targeted or required for the different components or at least some sense of the combined progress on cost that is needed from the baseline or cell build (CB) 1 design. The rest of the plan is crisply focused on overcoming the barriers to fast charge (FC), but the approach to reaching low cost is not so apparent. Overall, the plan to improve the technical performance of the cells is excellent and very comprehensive.

The development of pre-lithiation processes is depicted on Slide 5 as being “parallel” to the other optimization work, which is a bit of a risk, but it appears that some data on pre-lithiation approaches in the leading pouch-cell candidates will be available as early as CB 2, which is probably okay. All of the work appears to be feasible; the substantial progress to date at the halfway point of the project supports that conclusion.

Reviewer 3:
Zenlabs is trying to make low-cost, fast-charging batteries with targeted cycle and calendar life by developing novel electrolyte formulations and optimizing cell design. The selection of a high-nickel (Ni) NMC cathode and SiO_x anode is currently the mainstream route for LIB development.

Reviewer 4:
Zenlabs is starting from a cell chemistry where they achieve 310 milliamp-hour (mAh)/gram (g) and can achieve 1,000 cycles at C/1 charge and discharge. The goal is to meet the other USABC goals of 350 Watt-hours/kilogram (Wh/kg), good high- and low-temperature performance, and fast charge. The company also wants to deal with the gassing of Si-based cells and prelithiation and has set quite a few goals for itself. Most of the research is trial and error. There does not appear to be much chemical analysis to understand why one electrolyte is providing more functionality than another.

Reviewer 5:
For cells using significant amounts of Si, the swelling of the cell must be addressed. This appears to be completely missing from the approach. The reviewer suggested that the project team please measure the reversible volume change during one charge and discharge cycle along with the irreversible volume change after many cycles. Additionally, the heat generated with respect to the silicon hysteresis could also be important for fast charging; please measure this contribution.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
While it is still possible that the project’s goals will not be reached, the progress to date is excellent. The baseline cell design and materials were demonstrated at 1C/1C cycling at high capacity (310 Wh/kg at C/3) and cycle life of 1,000 cycles. The corresponding CB 1 reached nearly 700 cycles in fast-charging (4C/1C) testing, and the coin cell data for several new formulations and combinations look very promising to improve upon those results in the upcoming CB 2. If the CB 2 cells do not reach the 1,000-cycle goal for fast charge, they will probably be very close.

There is still a risk that gassing might be a problem—less progress on that concern was apparent from the results so far—but the project appears to be in very good shape and on track. The cell reproducibility data were also noteworthy, suggesting that the manufacturing process for the high-Ah pouch cells is being well controlled. The progress to date strongly suggests that 40-50 Ah pouch cells will very likely be possible for the second half of the project.

Reviewer 2:
The reviewer commented that target metrics are very well identified, and research performance is measured against the target clearly.

Reviewer 3:
At about halfway into the project duration, the project team has made impressive progress. It has achieved 1,000 cycles with 80% capacity retention with an 11.7-Ah pouch cell at 1C charge/discharge rate and more than 600 cycles at 4C rate. They have delivered 34, 12-Ah pouch cells to be tested at National Laboratories.

Reviewer 4:
The cell performance with regards to cyclability and fast-charge capability is respectable. However, the classic challenges associated with electrolyte stability remain. It was also not clear to the reviewer if the prelithiation approach simply enables the project to “run out the clock” by cycling quickly and thereby avoiding calendar-life problems.

Reviewer 5:
The project team is able to achieve 1,000 cycles at 1C charge/discharge cycles, 600 fast-charge cycles, and over 1,000 dynamic stress test (DST) cycles. It appears they will achieve less than 3 years of calendar life. The team has investigated a handful of electrolyte formulations to get to this point. The reviewer did not see much on prelithiation or on temperature stability. The team is also developing the ability to deliver large cells as a final deliverable and is able to demonstrate reasonable reproducibility. The reviewer did not see a path for drastically improving calendar life.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaborating with Idaho National Laboratory (INL), Sandia National Laboratories (SNL), and the National Renewable Energy Laboratory (NREL) for testing of the cells will speed up the development process and also provides opportunities to hone in the subject-matter experts from the respective National Laboratories.

Reviewer 2:
The project is designed so that the National Laboratory partners are tasked with conducting tests and evaluation of performance. As long as the test cells are produced and delivered on time, there is not much else needed to coordinate the effort across the project team. But so far, the reviewer commented, the coordination and hand-off of test cells appears to be working well. It is also reasonable to assume that the National Laboratories will collaborate with Zenlabs on the interpretation of the test data, not just hand it over after the tests are complete.

Reviewer 3:
As an industrial company, Zenlabs has collaborations with three National Laboratories, a good combination for synergistic effects.

Reviewer 4:
Although the company does not mention it, it has lots of suppliers for electrolytes, SiO_x, and cathode materials.

Reviewer 5:
The reviewer was looking forward to seeing the contributions with regards to the work of SNL and NREL. Nothing was shown in this presentation.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Future research is well aligned to address the gaps in the existing the development process, according to the reviewer.

Reviewer 2:
The future research proposed is to the point and feasible, especially because the project team is trying to understand the reaction mechanism to guide the identification of the electrolyte formulations, the electrode materials, and cell design.

Reviewer 3:
The plan is to continue screening and down-selecting materials the project team receives from suppliers.

Reviewer 4:
The proposed future research is probably well focused on the remaining challenges: calendar-life improvement, an effective pre-lithiation process, reduced gassing, continued electrolyte and electrode

optimization, and large pouch-cell manufacturing. The latter two issues will likely require less attention than the first three issues.

Progress so far suggests that further improvement in cycle life under fast charge (6C perhaps instead of 4C?) and large pouch-cell manufacturing will be realized in CB 2 and CB 3. The priorities for the other three were not suggested. Which of these is the most challenging and will need the most resources? The calendar-life issue may be more difficult than expected. If, as suspected, it relates to SEI formation, this degradation mechanism may depend on the state of charge (SOC) at which the cell is aged.

Given that there could be lots of possibilities to explore and very limited opportunity to test theories and improvements (given the long test cycle required), a clearer plan on the approach to addressing calendar life would have been helpful. Gassing is another possible headache; it was not really clear to the reviewer where the team is in terms of this issue and therefore how much of the future work might have to be dedicated to this issue.

Reviewer 5:
The plan shown does not seem to address the fundamental limitations. It is difficult to see a path to success.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is strongly aligned with the USABC 2023 goals for low-cost FC batteries, which is consistent with DOE priorities for vehicle electrification. So, it is clear that project supports DOE objectives.

Reviewer 2:
The proposed research clearly meets the DOE objectives.

Reviewer 3:
The research and development of fast-charging, low-cost Li-ion batteries will accelerate commercial viability of electric vehicles.

Reviewer 4:
The project team is developing the ability to produce quality cells and want to make high-energy cells at a low price. This is fully in line with DOE's mission.

Reviewer 5:
The overall goals of DOE of cost down with improved performance are unlikely to be met with large Si content.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project has made significant progress so far and does not appear to have realized any costly risks so far, so the remaining resources would seem to be adequate for the remaining work. CB 3 cells should be able to be built and tested by the end of the project.

Reviewer 2:
Resources and collaborative effort with DOE National Laboratories are sufficient to carry out the research.

Reviewer 3:
The project team is making steady progress to the targeted objectives.

Reviewer 4:
The reviewer noted that resources are sufficient.

Reviewer 5:

This is a 50/50 cost share with DOE. The team could spend more if it wanted.

Presentation Number: bat251
Presentation Title: Cathode Materials for Next Generation Lithium-Ion Batteries: Design, Synthesis, and Characterization of Low-Cobalt Cathodes
Principal Investigator: Jason Croy (Argonne National Laboratory)

Presenter

Jason Croy, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

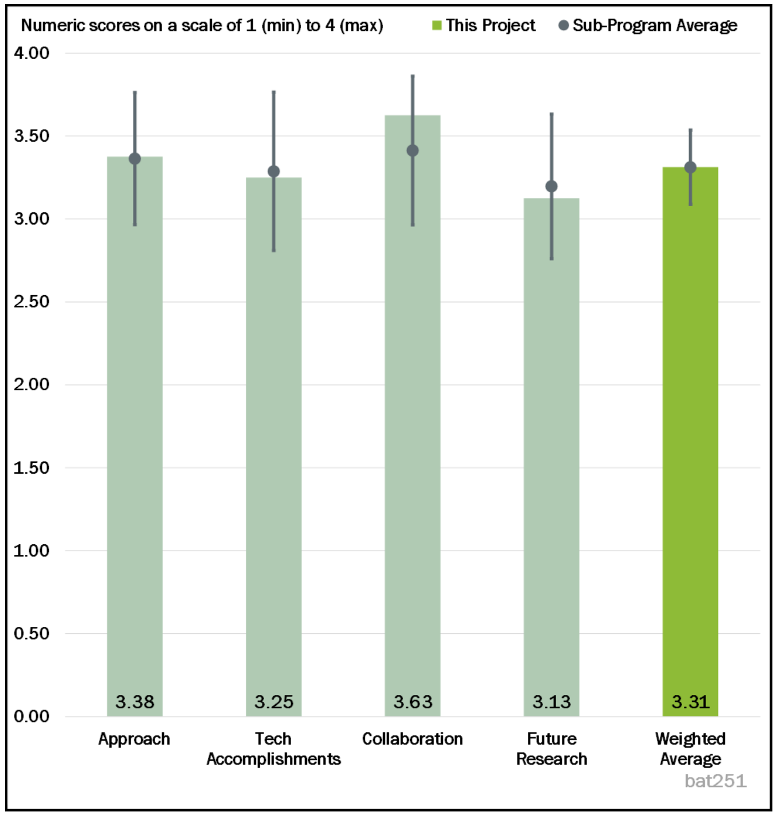

Figure 2-4 - Presentation Number: bat251 Presentation Title: Cathode Materials for Next Generation Lithium-Ion Batteries: Design, Synthesis, and Characterization of Low-Cobalt Cathodes Principal Investigator: Jason Croy (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
In this project, the team proposed two approaches for lithium nickel dioxide (LNO)-based and Mn-rich-based oxides to reduce the Co content in layered cathodes. These two approaches are feasible to realize the purpose to eventually eliminate the use of Co in layered cathodes.

Reviewer 2:
Work was focused on studying the nickel oxide cathode and other low-Co materials. Systematic study of the effect of Mn doping in nickel (Ni) and Al coating on Ni shed a good light on the properties.

Reviewer 3:
Focusing on LNO and Mn-rich oxides is relevant and adequate. The work is well designed to generate reliable data and improve understanding of low-Co options

Reviewer 4:
The reviewer found the electrochemical results obtained with the LNO system to be impressive. The project team introduced aluminum (Al) as a dopant by ALD and wet-chemistry coating before high-temperature calcination. It could be of interest to see if the Al can be incorporated into the precursor structure during calcination, too.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
As mentioned earlier, the reviewer observed that the LNO electrochemical results were great. The LNO-based oxides with truncated polyhedron and octahedron morphologies are very interesting; they can help to better understand the electrolyte reactivity on the particle surfaces. Doping with Al using ALD resulted in uniform distribution of the additive improving the cycling performance. The study with single-crystals powders in collaboration with the Theory Group may yield important practical and theoretical insight.

Reviewer 2:
In the last year, the team has made significant progress in both directions of the studies. Specifically, the temperature-evolution behavior of pure LNO is quite meaningful and the electrochemistry results are beautiful. Also, the smaller introduction of Co into lithium manganese nickel oxide (LMNO) (only 5%) could drastically improve the electrochemical performance, which is also a striking achievement.

The reviewer offered the following specific areas to consider:

- It would be beneficial to involve the morphology evolutional results of LNO synthesized at 650°C, 665°C, and 685°C. The morphological differences might also be a reason to cause the distinction of electrochemistry.
- The Al surface treatment for lithium nickel cobalt oxide (LNCO) is unclear. Using X-ray photoelectron spectroscopy (XPS) depth-profile or cross-sectional energy-dispersive X-ray spectroscopy (EDS) line profile or mapping could provide the insight into the different bulk Al incorporation between ALD and wet coating.
- There needs to be more information to explain the reason why the ALD coating can introduce better bulk Al incorporation than wet chemistry.
- In a recent paper published in the *Journal of the Electrochemical Society* (JES), the author claims the unnecessary usage of Co in layered cathodes, it would be worth understanding the perspective from the team to consider having some minor Co content in both LNO-based and Mn-rich-based compositions.

Reviewer 3:
The grain-boundary transformation study and ordering are revealing, which can help with the design of future materials, especially the addition of a small amount of Co and that on Li/Ni exchange. It would have been useful to see electrochemical performance for more cycles beyond 100.

Reviewer 4:
The reviewer remarked that the good progress to generate more reliable LNO data is very useful.

Data on the impact of doping on LNO performance are relevant, but the reviewer was not sure how much new information was generated versus prior work. The reviewer did not understand the implication of particle-structure relevance.

Data on Mn-rich cathodes seem to confirm the importance of Co. It was hard to understand if the results suggest that removing Co is hard or impossible or provide some glimmer of hope.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There was excellent collaboration among the teams.

Reviewer 2:
In this project, all participants mainly from five National Laboratories have shown the good quality of the experimental results, which is an indication of close collaborative relationships.

Reviewer 3:
The reviewer found the collaboration within the groups to be interesting. In particular, it is becoming very important for the collaboration between the theoretical group with the synthetic group.

Reviewer 4:
The reviewer noted that there was very good collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The team has proposed reasonable plans for next-year studies. The suggestion would be trying to avoid the usage of Co completely by considering other alternative elements, such as Mg, Al, etc.

Reviewer 2:
Re-examination of $LiNiO_2$ seems very important, in particular after the very good capacity results obtained by the project team. The Al dopant seems to be giving important improvements. Maybe introducing Al during calcination can be explored, too.

Reviewer 3:
The project has a good path forward including theoretical modeling.

Reviewer 4:
The focus on surface modifications and characterization is adequate.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project supports the overall DOE objectives and its purpose to reduce or even eliminate the usage of Co in layered cathodes, which is a critical topic of novel cathode compounds.

Reviewer 2:
This project is very relevant for the overall DOE objective of not using Co in the cathode powders. The team has shown great results and understanding of powders with no Co and very little Co contribution.

Reviewer 3:
Low-Co cathode material is relevant to the sustainability of Li-ion battery technology.

Reviewer 4:
This project supports DOE goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
To date, this project has delivered sufficient and meaningful results to meet the requirements of milestones.

Reviewer 2:
The project team may need additional support in case a production process needs to be scaled up.

Reviewer 3:
The project team has adequate resources and expertise.

Reviewer 4:
Resources seemed sufficient to the reviewer.

Presentation Number: bat252
Presentation Title: Cathode Materials for Next Generation Lithium-Ion Batteries: Diagnostic Testing and Evaluation of Low-Cobalt Cathodes
Principal Investigator: Dan Abraham (Argonne National Laboratory)

Presenter

Dan Abraham, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

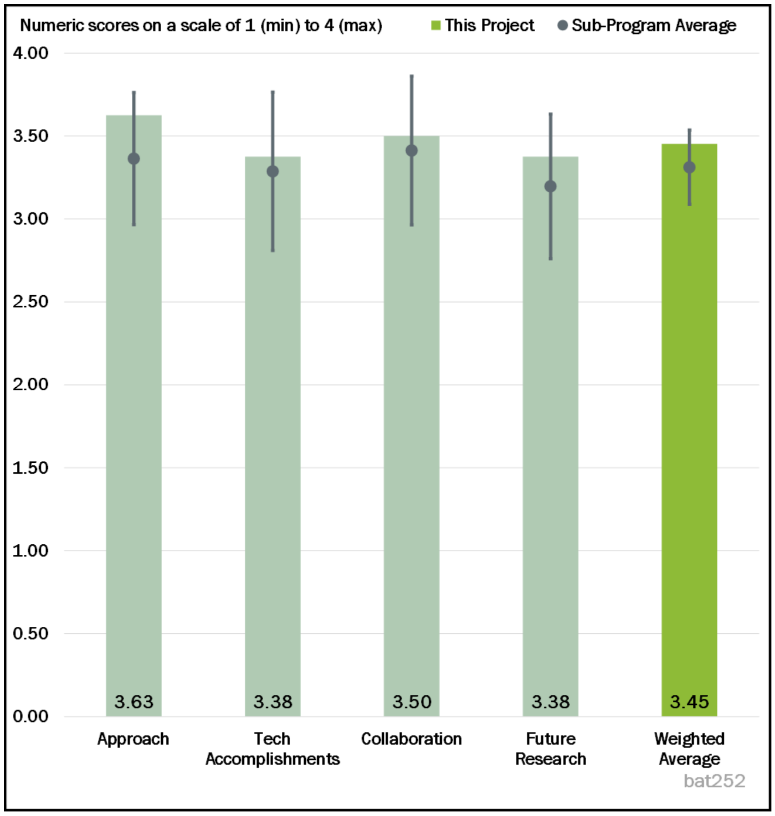

Figure 2-5 - Presentation Number: bat252 Presentation Title: Cathode Materials for Next Generation Lithium-Ion Batteries: Diagnostic Testing and Evaluation of Low-Cobalt Cathodes Principal Investigator: Dan Abraham (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that this is an excellent multifaceted approach consisting of oxide development, cell testing, and post-mortem characterization.

Reviewer 2:

According to the reviewer, there is excellent work on the diagnostic testing and evaluation, which can be widely used by many other researchers. Most relevant aspects of the cathode material and testing are covered.

Reviewer 3:

The reviewer found the approach to be very good as the project team gradually replaced Co with Mn to study its effect on performance. The team has also fully replaced Co in one of these oxide cathodes. The capacity results were very impressive when testing Ni:Mn at 9:1. There was strong synthetic effort coordinated with testing and analytical post-characterization.

Reviewer 4:

In the last year, the team has determined the approaches of using electrochemical methods combined with some characterization techniques, such as differential electrochemical mass spectroscopy (DEMS), Fourier transform infrared (FTIR), nuclear magnetic resonance (NMR), differential scanning calorimetry (DSC), XS, Raman, etc., to understand the electrochemical mechanism of low-Co layered cathodes synthesized by colleagues. The techniques and protocol selections are reasonable and reliable.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented that there were very good capacity results with the pure Ni and Ni-Mn cathode material. Important results were obtained with in situ measurements, such as Raman, FTIR, and XPS. These methodologies could be extremely important to study and identify the degradation mechanism of these oxides, in particular the SEI. The results with solid-state NMR are giving important insight as they can detect bulk and surface Li.

Reviewer 2:
In the last year, the team has generated fruitful and comprehensive results for four types of Ni-rich and low- to no-Co cathodes. The long-term half-cell and full-cell results indicated the favorable performance of NMC-900505 and NM-9010 with the impedance, structural, and chemical studies. A deep understanding of these cathode compounds has been established.

Here are some specific comments from the reviewer:

- For the DEMS tests on these four cathodes, it would be worth knowing the reason to choose 4.2 V with prolonged holding to collect the O_2/carbon dioxide (CO_2) gassing data. In general, the preferred way to collect the gassing data would be during the galvanostatic charging at higher voltage, such as greater than 4.5 V.
- For DSC results, the current data can support the claim on “all four compounds have similar total heat release.” However, the onset temperature of the first exothermic peak is also significant. Any observations or analysis on this should be discussed.

Reviewer 3:
Work is based on LNO structure in which a small amount of Co or Mn is doped. It is interesting to see that hold at 2.5 V capacity, which helps recover capacity. Also, the performance of the 0.05 Co and 0.05 Mn containing cathode is the best performing. In addition, the role of additives is examined.

In the gassing behavior, it is not clear to the reviewer why other organic gases (other than O_2 and CO_2) are absent. Is it an experimental error? Gases containing hydrogen (H) and F atoms were expected.

Reviewer 4:
According to the reviewer, there are useful insights that cell impedance after cycling is mostly due to the cathode. This is consistent with other prior work but provides more details and useful additional insights.

The best performing material seems to be the one with Co. Is this suggesting that some Co is necessary?

The gassing problem was highlighted but potential solutions were not discussed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration was excellent.

Reviewer 2:
Collaboration seems to be strong between the different groups at ANL, NREL, Oak Ridge National Laboratory (ORNL), Lawrence Berkeley National Laboratory (LBNL), and Pacific Northwest National Laboratory (PNNL). Furthermore, the student support at University of Illinois, University of Rochester, and Oregon State University is very important for future developments in this field.

Reviewer 3:
In the last year, the team showed a good demonstration of the collaborative studies by testing synthesized materials from the collaborators and coordinated with other advanced characterization from collaborators.

Reviewer 4:
According to the reviewer, there was good collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The team has included nearly all necessary next steps for the upcoming fiscal year (FY) studies, such as the further diagnostics and characterization of scaled-up and surface-coated samples. One suggestion is to utilize the advanced synchrotron-based spectroscopic techniques in this team to conduct some in-situ cell characterization, such as hard- or soft- X-ray absorption spectroscopy as well as the surface X-ray diffraction or neutron diffractions to understand more about the chemical and structural evolution upon cycling.

Reviewer 2:
The study of performance degradation with ex-situ and in-situ spectroscopies should be encouraged. The scale-up of the synthetic efforts should continue. It is not clear to the reviewer, based on the presentation, why the project team is producing very small batches of this material (less than 100 g).

Reviewer 3:
The reviewer noted that this is an extension of the present work with additional in-situ spectroscopic techniques.

Reviewer 4:
Scale-up of additional oxides and the focus on surface optimization are relevant. Establishing electrochemical models to explain performance of low-Co oxide system would be very valuable.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer remarked that this project supports the overall DOE objectives of eliminating the usage of Co in layered cathodes, which is quite important for the development of high-energy cathode materials.

Reviewer 2:
Yes, this project supports the overall objective of decreasing the amount of Co used in these layered oxides. The project team already presented very good results with material that contains no Co, such as LiNi0.9Mn01. It would be interesting to know if the Mn-containing oxides are difficult to calcinate as it requires full oxidation of Mn during this process.

Reviewer 3:
Low-Co cathode material will help move the technology forward.

Reviewer 4:
The project supports DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The range of techniques available for the project is impressive.

Reviewer 2:
This project has delivered satisfactory experimental results to meet the requirements of milestones, according to the reviewer.

Reviewer 3:
There are sufficient resources.

Reviewer 4:
This project may require additional support in case a scale-up of the precipitation process becomes necessary.

Presentation Number: bat253
Presentation Title: Cathode Materials for Next Generation Lithium-Ion Batteries: Theory and Modeling of Low-Cobalt Cathodes
Principal Investigator: Hakim Iddir (Argonne National Laboratory)

Presenter

Hakim Iddir, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

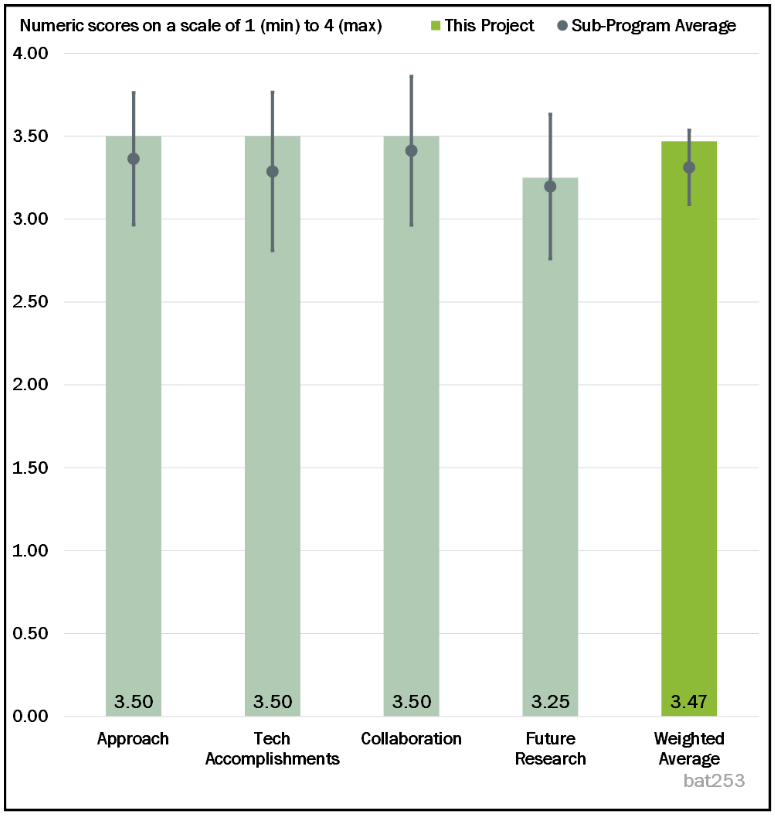

Figure 2-6 - Presentation Number: bat253 Presentation Title: Cathode Materials for Next Generation Lithium-Ion Batteries: Theory and Modeling of Low-Cobalt Cathodes Principal Investigator: Hakim Iddir (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer found this to be a very interesting approach where theoretical calculations are confronted with experimental results and, in some cases, help guide the experimental work. The project is well designed and feasible.

Reviewer 2:

This modeling work is appropriate to link very many experimental projects that are ongoing on low-Co cathode material design. The project could help link various studies together in providing a unified understanding that will help move the field forward.

Reviewer 3:

The team mainly leveraged the first-principle simulation tools to identify the role of Co introduction to the Li-Ni cation mixing, local structures, and Ni-Mn migrations. With some experimental results of single-crystal Ni-rich cathode materials, the feasibility of this approach has been confirmed.

Reviewer 4:

Use of modeling to understand the role of Co is a promising approach, according to the reviewer.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The team accomplished the simulation tasks to justify the minimum amount of Co needed to stabilize the layered structure while suppressing Li-Ni cation mixing and Ni-Mn migrations. The results validated the existence of Co as inducing the ordered domain formation to increase the formation energy of cation mixing, which is beneficial for the perfect layered structure stabilization.

Reviewer 2:
The production of facet-dependent segregation in layered oxides was very interesting to the reviewer. It could be of great interest to really understand why the calculations predict a minimum of 1-3% Li-Ni exchange for all $LiNi_{0.5}Mn_{0.5}O_2$ configurations. Another interesting result is about the "zigzag" configuration on the Mn5050 oxide. Is it more stable because there is additional Mn-Ni atomic overlap in that geometry?

Reviewer 3:
Various insights are interesting, including energy correlation with Ni-Mn bonds, the difference between structures containing flower and zigzag patterns for Li-Ni exchange, dopant effect, and the dependence on the crystal facets. The principal investigator (PI) should show the comparison with the experimental electrochemical data to develop a confidence in the modeling results even though the NMR and lattice data are presented and compared.

Reviewer 4:
The team has generated useful insights into role of Mn-Ni interaction and effect of Li-Ni exchange. The impact of calcination and cooling conditions is also elucidated. Screening of dopants was comprehensive, but the reviewer struggled to understand the conclusions.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
It seemed to the reviewer that there is very good interaction within the groups, in particular between the theoretical researchers and the experimentalists. The reviewer was eager to see if the team can come up with a simple model that can explain the theoretical calculations and stability studies (energy numbers). It is nice to see that this study also helps the new generation of researcher at the University of Illinois, University of Rochester, and Oregon State University.

Reviewer 2:
The team used NMR, scanning transmission electron microscopy (STEM), and molten-salt synthesis to build the experimental complementary information about the local Li environments and the surface configuration of single-crystal particles. These collaborative results have proven the significance of the combination between simulations and experimental works.

Reviewer 3:
It is a good team and there is excellent collaboration.

Reviewer 4:
There is good teamwork.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future work is effectively planned and structured.

Reviewer 2:
The refining NMR fitting seems very important, and it seemed to the reviewer that it gave useful hints about the local Li-environments. It could be of interest to know how truncated polyhedron and octahedron morphologies have been prepared without revealing confidential information. That could be important at some point to judge if the process is scalable.

Reviewer 3:
The project proposed a clear next-step plan for this project. However, it could be more comprehensive if the collaborative studies between simulations and experimental works in this project can be further fused to generate more reliable results.

Reviewer 4:
Effect of element segregation would be useful. The reviewer was not sure if the kinetic modeling can be done that will be of useful (long enough) time scale.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer stated that this project supports the overall DOE objectives of the synthesis and understanding of high-energy and long-lifespan Ni-rich cathodes, which are quite important for the development of next-generation cathode materials.

Reviewer 2:
The project supports the overall objective by replacing Co with Mn. Furthermore, the theoretical work adds a lot of validity to the experimental results.

Reviewer 3:
The work will help with fundamental understanding of cathode materials.

Reviewer 4:
The project supports DOE goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that this project has delivered sufficient experimental results to meet the requirements of milestones.

Reviewer 2:
The PI has adequate computing facilities.

Reviewer 3:
There are sufficient resources.

Reviewer 4:

The resources may not be sufficient if, at some point, a production process for these cathode powders has to be scaled up.

Presentation Number: bat293
Presentation Title: A Closed-Loop Process for End-of-Life Electric Vehicle Lithium-Ion Batteries
Principal Investigator: Yan Wang (Worcester Polytechnic Institute)

Presenter

Yan Wang, Worcester Polytechnic Institute

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

80% of reviewers indicated that the project was relevant to current DOE objectives, 20% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

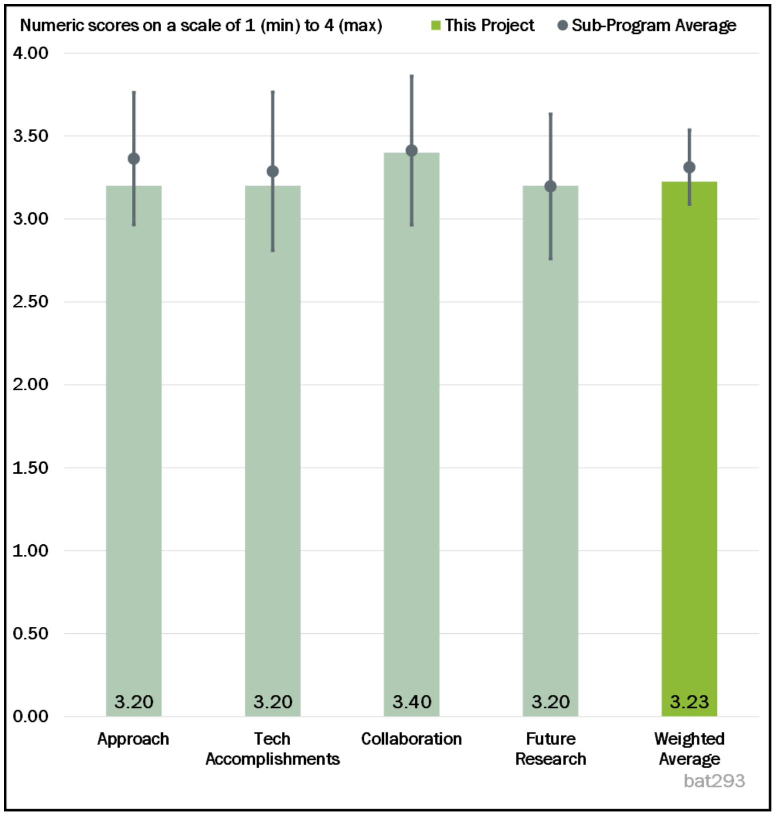

Figure 2-7 - Presentation Number: bat293 Presentation Title: A Closed-Loop Process for End-of-Life Electric Vehicle Lithium-Ion Batteries Principal Investigator: Yan Wang (Worcester Polytechnic Institute)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Technical barriers impacting the project are identified upfront in the NMC research.

Reviewer 2:

The reviewer believed the idea is to collect Li-ion cells and, independent of the chemistry, collect the internal material and convert it to NMC622. This is a reasonable team where A123 will make ad test cells, Battery Resourcers will collect the Ni-based cathode, and then Worcester Polytechnic Institute will determine how to make fresh NCM622 from the material. The goal of the project is to make an NMC622 that is cheaper than starting from scratch. The team needs to perform the cost analysis.

Reviewer 3:

This appears to do recycling via complete decomposition of the materials back into virgin salts, which are then fed into the precursor precipitation process. It was unclear to the reviewer what the value to the larger community is for this approach. Regardless, the approach could certainly be more clearly communicated in the slides.

Reviewer 4:

The project was fairly well planned out, including a reasonable test plan, such that the technical barriers are mostly being well addressed. The cost barrier is adequately being addressed—there is at least some cost model data that indicate that the central recovery process could produce material that is 25% cheaper than virgin. Cost would have been better addressed if some work had been done to show the cost saving estimated for different levels of Co in the NMC; presumably, the cost advantage is less for lower Co content. According to the reviewer, there was no discussion about what percentage Co concentration in the recovered material would be for the quoted 25% savings to be expected. Similarly, like last year's comments, it is not all that clear how the sustainability target is being addressed. It would have been helpful to determine the percentage recovery of the waste material and how much is converted to usable cathode material. While this affects the cost savings, it probably affects the sustainability challenge more. It will not be very sustainable if only a small percentage of the end-of-life (EOL) material can be recovered. However, the performance and supply barriers are well addressed, and the project was well designed, overall.

Reviewer 5:
Recycling end-of-life LIBs to produce high-Ni NMC cathodes is a right strategy to reduce the cost and environmental impact. Not much detail about the technical approach is revealed in the report, but based on the testing results, the reviewer said that the project is well designed and feasible.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Measured progress has been made in the research against the performance indicators.

Reviewer 2:
The reviewer noted that 24, 1-Ah NMC622 cells made with recycled cathode materials were delivered for testing. The results are comparable with the cells made with fresh materials. The team also tested one 11-Ah cell and got promising data.

Reviewer 3:
The project team needs to be able to collect the Ni-based cathode material and develop a scalable coating method on the way to producing NCM 622. The team has a reliable process for making coated NCM 622. It appeared to the reviewer that the team can make a material that is about 2% short of a control chemistry. The rate capability in 1-Ah cells is comparable. The team also demonstrated that it can generate large batches of materials that are comparable to a control, and the reviewer believes it is possible to make materials 25% cheaper than materials made from scratch.

Reviewer 4:
The project is nearing completion and appears to be generally on track to meet all deliverables although the testing of the 1-Ah cells and the fabrication and testing of the 11-Ah cells appear to be slightly behind and may need a short extension of the project. However, the project succeeded in producing the required 15 kg of recovered material to fully support the test plan, and the coin cell data indicate that the material quality is likely high enough to give good results. There is a reasonable probability that the 11-Ah cell testing will demonstrate that the recovered material is roughly equivalent to the virgin material control cells. So, the project will have a reasonable level of impact as expected.

However, even though the team notes that it has used diverse sources of spent battery material as inputs to the recovery processing, it was still not clear to the reviewer what levels of impurities can be handled, what diversity in the feedstock can be accommodated and still achieve process efficiency high enough to make the cost saving possible, or whatever other limitations on the processing window or feedstock are required to make the process feasible. Until these processing windows and feedstock requirements are determined, the impact of this project will be limited mostly to a demonstration that, at least under a certain set of conditions, shows the recovery process is possible and produces good material.

Reviewer 5:
It appeared to the reviewer that the team is using a relatively well known and understood cathode manufacturing processes. The technical accomplishment is not clear. Where is the value in this work?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaborating with private industry and other DOE National Laboratories helps to scale up the commercialization process for this research effort. Fiat Chrysler Automobiles, General Motors (GM), and Ford involvement helps to identify the broader industry needs and their thought process.

Reviewer 2:
The project team has formed effective collaborations with A123 and ANL (for testing) and Battery Resourcers (for materials).

Reviewer 3:
The project appears to have assembled a good team with all of the expertise needed; there has been close cooperation among team members, which has helped keep the project roughly on schedule and looking to complete its test plan soon. One might expect the vehicle manufacturers to provide more than just spent batteries of various types—did they provide guidance on the testing plan, the analysis of the results, etc.? A close collaboration with the manufacturers could have included that kind of feedback loop. However, at least all of the necessary coordination of activities appears to have happened fairly smoothly with each partner participating at the required level to get to the end of the project.

Reviewer 4:
The reviewer noted that the team has established collaborations with reputable companies all along the recycling chain.

Reviewer 5:
According to the reviewer, collaboration and coordination across the project team is fine.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The future research proposal fits very well with gaps identified and provides a continuous improvement.

Reviewer 2:
Future plans are clear. The team is going to measure the cyclability of its materials compared to a control in 1-Ah and 11-Ah cells, refine their cost model, and look into producing higher Ni-content materials.

Reviewer 3:
There is not much left in the project, and the plan to complete the 1A-h testing and the 11-Ah build/test is entirely appropriate at this point. An update on the rough cost-savings estimate specifically for NMC622 or NMC811 would be nice if possible.

Reviewer 4:
It is important to build a cost model to show the economic benefits. Moving to NMC811 is also right direction. The reviewer also suggested performing an assessment on the nature of resource savings, like how much Co and Li are reused in the batteries.

Reviewer 5:
This project is ending.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Yes, the project is/was well aligned with DOE priorities to establish a recycling capability for LIBs. Demonstration that the cathode material can be recovered and chemically reprocessed using co-precipitation chemistry to usable material at a cost savings is an important milestone for DOE and the EV community, and it will provide a benchmark for other recycling efforts that are more “direct” and try to recover, re-lithiate, and reuse the cathode mass more directly.

Reviewer 2:
Reducing the cost and environmental impact of battery production is in line with DOE objectives.

Reviewer 3:
Developing a way to collect and reuse materials from aged cells is critical to a sustainable ecosystem, which is at the core of DOE’s activities.

Reviewer 4:
The reviewer stated the project meets the overall DOE objectives.

Reviewer 5:
The relevance and usefulness of this project was not clear to the reviewer. Perhaps it was poor communication in the slides and the recorded presentations. Regretfully, the reviewer was unable to submit questions before the cutoff.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Partnering with private industry and DOE National Laboratories provides a sufficient resource to carry out the research.

Reviewer 2:
With just some cell fabrication and testing remaining, the project appears to have enough resources to complete the project.

Reviewer 3:
The project is 90% completed by the time of the report.

Reviewer 4:
The resources appeared sufficient to the reviewer.

Reviewer 5:
The resources are sufficient.

Presentation Number: bat332
Presentation Title: High Electrode-Loading Electric Vehicle Cell
Principal Investigator: Mohamed Taggougui (24M Technologies)

Presenter

Mohamed Taggougui, 24M Technologies

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

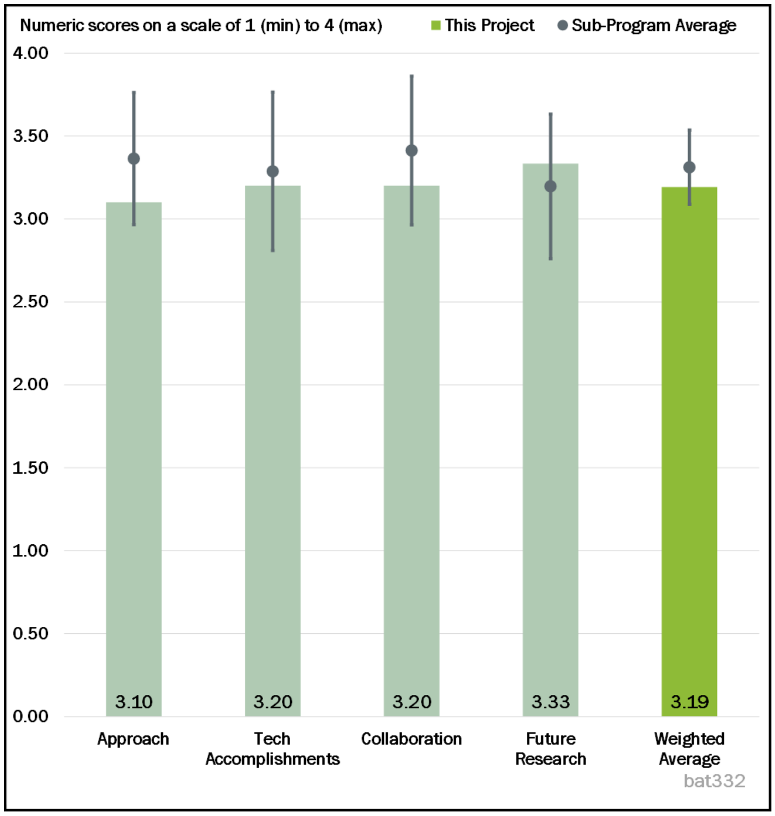

Figure 2-8 - Presentation Number: bat332 Presentation Title: High Electrode-Loading Electric Vehicle Cell Principal Investigator: Mohamed Taggougui (24M Technologies)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that the project clearly addressed the technical barriers associated with the high-energy battery systems in abuse tolerance and reliability aspects of Li-ion batteries.

Reviewer 2:

The project is based on 24M's semi-solid electrode technology, which enables high-electrode-loading cells for electric vehicles. The thick electrode format reduces or eliminates binders and separators and thus enables 25% cost reduction.

Reviewer 3:

Increasing the electrode loading is a direct way to lower the cost of cell. 24M presents a novel approach to manufacturing these thick electrodes. This project represents an interesting alternative to the standard approach to LIBs. With that said, the ultra-high loading electrodes have trade-offs that are unlikely to be overcome, such as electrolyte-transport limitations and an overall high cell direct current internal resistance (DCIR) due to lack of coated area (DCIR scales with coated area to the first order).

Reviewer 4:

The project was clearly well planned and executed. For the most part, the team appears to have focused on the correct barriers and provided reasonable solutions to most of them. From the milestone chart on Slide 7, electrolyte optimization and down-selection were part of each phase, but it was not clear to the reviewer how aggressive the program plan was in identifying and developing higher conductivity liquids that would have been more likely to reach higher energy capacities and/or higher C rates. It is possible that conservative choices in the electrolytes considered were made to ensure that viable cells could be produced and cycled to 1,000 cycles with 80% capacity retention—which would mean that the energy-capacity barrier and fast-charge barriers might not be well addressed by the project. Nevertheless, the project structure appears to have been sound, and generally most barriers were addressable within the design of the project.

Reviewer 5:
In general, the project approach is to use a semi-solid formulation to make thick electrodes, which should minimize the need for a large fraction of inactive components, thus saving dollars per kWh. Most of this year was spent on large cell construction and cycle testing. The reviewer's guess is that in its proposal the company said it would reach 350 Wh/kg but in the end achieved 276 Wh/kg. It would be interesting to know what did not work out in their approach to achieving this value.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project remained on schedule, met its milestones, achieved most of its performance goals, and, most importantly, demonstrated that a reasonably high-performing EV cell could be made with semi-solid electrode processing. As the team noted in the presentation, there is still some work to improve the EV cells to increase energy capacity, fast-charge capability, and low-temperature capacity retention, but overall the progress made by the project was noteworthy and should have an impact on EV battery technology.

Reviewer 2:
The deliverable cells (2.9 Ah and 52 Ah) achieve high energy density and specific energy, more than 1,000 cycles before EOL, and great tolerance property in electrical and mechanical abuse tests.

Reviewer 3:
The team made several large cells and met its deliverables in terms of number of cells and cycle life by achieving 276 Wh/kg, but there is are no calendar-life data shown. The reviewer mentioned excellent abuse tolerance. It would be nice to know why this cell design is capable of improved abuse tolerance over typical Li-ion cells.

Reviewer 4:
Technical accomplishments show more pictorial representation of the deliverables. It would have been beneficial to have a little more description associated with the pictures.

Reviewer 5:
The performance of the cells speaks to a respectable level of maturity. It was not clear to the reviewer that the main barriers will ever be overcome to enable commercialization in the automobile sector. More work showing the limitations related to charging would have been appreciated. The final-cell energy density was also not that impressive considering the ultra-high loadings. The reviewer assumed this is due to the high electrode porosity associated with the semi-solid electrodes.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Although there were only a limited number of partners in this project, any project of this size, duration, and complexity requires close coordination and collaboration across the partner set. This project excelled in this factor—optimization and down-selections occurred on time, cells got built and delivered, and independent testing got done. The reviewer remarked that a highlight of the project was its collaboration and coordination.

Reviewer 2:
The reviewer noted that the project team has collaborated with two National Laboratories on performance tests.

Reviewer 3:
The project team is fairly self-sufficient at this point. It is relying on ANL and SNL for cycle life and abuse testing, respectively.

Reviewer 4:
Collaboration and coordination seemed okay to the reviewer.

Reviewer 5:
Collaborating with ANL and SNL is good to utilize their testing resources. Industry partners will add more value in addition to the DOE National Laboratories if the long-term goal is to commercialize.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Researchers identified the value-creation opportunities in the ultra low-cost and fast-charge automotive-capable cell.

Reviewer 2:
The company has identified future technical opportunities on making ultra low-cost and fast-charging batteries. Their current deliverable cells are of C/3 charge rate. An improved charge rate will increase the commercial compatibility of their products, according to the reviewer.

Reviewer 3:
Future research includes improving the calendar life (the reviewer was not sure how) and improving the fast charge by using a bimodal distribution of the cathode material and increasing the conductivity of the electrolyte (again the reviewer was not sure how).

Reviewer 4:
Project is complete.

Reviewer 5:
This criterion is not applicable as the project has been completed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project clearly supported DOE objectives by addressing an important question about whether a reasonably high-quality EV battery could be produced using a semi-solid electrode manufacturing process where the same liquid serves as the solvent, carrier, and cell electrolyte. The project reasonably demonstrated that a viable EV cell with moderately high energy density (276 kWh/kg), good abuse-testing characteristics, and low-performance variability could be produced using the semi-solid production approach and therefore at the significantly lower cost promised by this manufacturing approach (e.g., fewer steps, lower balance of materials required). Although the Phase 3 cell will not meet the USABC 2020 goal for cell-level, usable specific energy, the results of the project should nevertheless support DOE objectives by demonstrating the general viability of the novel production technique for high-quality EV batteries.

Reviewer 2:
This project enables industrial-scale production of low-cost and high-performance batteries for electric vehicles.

Reviewer 3:
The project seeks to meet DOE's goals for energy-density goals, cycle life, and improved abuse tolerance. The technology appears to meet the cycle-life and abuse-tolerance targets but falls short on energy density, fast charge, and calendar life. There is no explanation provided.

Reviewer 4:
The project has an Interesting approach to reduce cost. The reviewer remarked that it is good to have done the evaluation although it is unlikely to be implemented.

Reviewer 5:
The reviewer stated that the project meets the overall DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The researcher is capable of carrying out the research with minimal collaboration and has sufficient resources.

Reviewer 2:
The company seems to be making good progress.

Reviewer 3:
This is a completed project with 50% funding share from the company.

Reviewer 4:
The reviewer stated that resources are sufficient.

Reviewer 5:
The project was completed in 2019.

Presentation Number: bat355
Presentation Title: Development of High-Performance Lithium-Ion Cell Technology for Electric Vehicle Applications
Principal Investigator: Madhuri Thakur (Farasis Energy)

Presenter

Madhuri Thakur, Farasis Energy

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

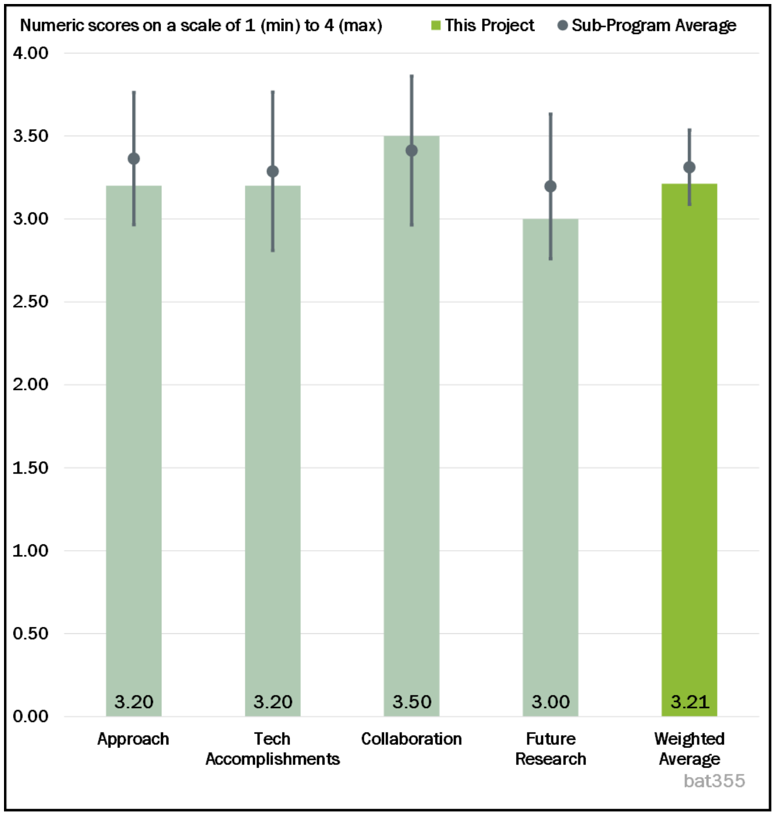

Figure 2-9 - Presentation Number: bat355 Presentation Title: Development of High-Performance Lithium-Ion Cell Technology for Electric Vehicle Applications Principal Investigator: Madhuri Thakur (Farasis Energy)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The technology approach has been carried out by addressing key current barriers to achieving high capacity, long life cycle, and safety thoroughly.

Reviewer 2:

The main target of the project is to develop a high energy-density battery (330 Wh/Kg beginning of life and 280 Wh/Kg at 1,000 cycles) at low cost ($0.10/Wh). The approach is a combined effort among National Laboratories and industrial companies to improve electrode chemistry (Si-based anode and Ni-rich cathodes), electrolytes, and cell design. This approach seems to work well as it teams up expertise of different fields to systematically tackle the barriers in battery advancement.

Reviewer 3:

For this complicated problem, the team plans to look at cathode materials from seven different suppliers and electrolytes from three suppliers and investigate electrode formulations and cell designs. The reviewer indicated that the team does not explain how it plans to arrive at a final chemistry and a final cell design.

Reviewer 4:

The reviewer asked for the team to please put greater focus on volumetric energy density and swelling (during one cycle and after many cycles). A company such as Farasis should have the ability to target these more practical matters compared to a university or National Laboratory. The reviewer noticed the response to previous reviewers' comments, but the statement from the presenter should be supported by data. This should be considered a higher priority than it is.

Reviewer 5:
The project has been following a fairly comprehensive work plan with a large test matrix of anode material, cathode material, electrolytes, additives, and even binders in pursuit of the Gen 2 goal early in 2021. Although comprehensive, it looks very much like trial-and-error. If possible, it would have been better if there had been some indication of why certain combinations have been tried and why others have not. Is the approach simply to try each and every possible combination of the available material? It looks like the number of candidates here was at the limit of the project time available—any more and the project would have been further behind.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Sufficient progress has been made in evaluating the active anode and cathode materials and compared very well against the performance indicators.

Reviewer 2:
The project team has designed and fabricated the Gen 2 cell of 330 Wh/Kg in 500-mAh capacity for the test as scheduled.

There is no cost assessment for making the cells in pilot-plant scale. Cost saving is one of the major objectives and the project is close to completion.

Reviewer 3:
The team does end up achieving 1,000 DST cycles and 310 Wh/kg; however, it did not appear to the reviewer as though the team will reach a year of calendar life at 100% SOC. The team moved to SiO but required a prelithiation step to improve the energy density. The cycle life has dropped to around 500 cycles. Moving to three other Si materials, the team gets back to 800 cycles at 330 mAh/g. It is not clear as to what led to the increase in energy and improved cycle life. The team does not mention the amount of carbon and binder it used for either electrode or the capacity per centimeter squared (cm^2) it achieved.

Reviewer 4:
The cycling depth of discharge appears to be very generous and perhaps not as aggressive as it should be for automotive applications. The reviewer asked the team to please consider cycling down to 2.8 V at least. There are no results shown for gassing at elevated temperatures, which could be a showstopper for automotive.

Reviewer 5:
The project certainly has made reasonably good progress toward its final goal and successfully delivered Gen 1 cells to the National Laboratory partner, which met performance targets (except for calendar life at high SOC). The prospect of delivering Gen 2 cells that also meet the performance targets when tested at the National Laboratories is pretty good based on the preliminary data provided for non-production-quality test cells that have been cycled to 800 cycles.

However, the cost target of $0.10/Wh does not appear to be addressed anywhere in the provided material. Where is the project in term of meeting its cost target in the Gen 2 cell to be delivered in early 2021? Also, the Gen 2 prototype data focused on capacity retention and did not include data on anode conductivity (discharge capacity rate [DCR]) and stability, so it was not entirely clear to the reviewer that this aspect has been fully investigated and brought under control for the Gen 2 demonstration. However, it does appear that most technical barriers are being overcome. Progress on the cost barrier was unclear to the reviewer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There are an outstanding number of partners on this project.

Reviewer 2:
The reviewer found excellent collaboration with many DOE National Laboratories and industry partners. Industry partners bring in the commercial point of view, and DOE National Laboratories add insight to the detailed aspects of development.

Reviewer 3:
There are many collaborators in this project: mostly material suppliers and National Laboratories for performance verification. It seemed to the reviewer like there has been very good coordination of the effort despite all of the required inputs. The delays in the project appear to have come from overcoming performance issues with the cells and not in getting materials, getting the cell fabricated, and getting the cells tested. All of that coordinated effort seems to be going well among the project partners.

Reviewer 4:
The team includes two National Laboratories and several industrial companies; all have different contributions.

Reviewer 5:
Cross interactions were not clear to the reviewer.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
There is not much left to do on this project, and the plan to finish and close out the effort is straightforward and logical. According to the reviewer, there are no issues here.

Reviewer 2:
To complete the project, the team will build 40-Ah cells with projected energy density of 310 Wh/kg.

Reviewer 3:
The reviewer noted that the project is ending soon.

Reviewer 4:
The reviewer did not see any future research areas from the researcher except building a 40-50-Ah cell.

Reviewer 5:
Despite being nearly complete (75% of the way there), the project team does not provide a future research slide.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is very well aligned with DOE objectives to reach 330-350 Wh/kg cells at a cost of $0.10/Wh. The project was specifically designed to meet these DOE goals within a 3-year project, again supporting DOE objectives for electric vehicles in 2022 and beyond.

Reviewer 2:
Batteries of high energy density, low cost, and longer cycle and calendar life will make the EV commercially viable.

Reviewer 3:
This project looks to improve cell capacity toward 350 Wh/kg with long cycle and calendar life. The project team is getting close to the first two.

Reviewer 4:
The reviewer said that Si is an important material to develop and potential aid DOE to achieve their goals.

Reviewer 5:
Research does meet the DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The research team has sufficient resources and is also collaborating with many DOE National Laboratories and including an industry partner also.

Reviewer 2:
The project appears to have sufficient, but not excessive, resources to complete the project as planned under the no-cost extension (NCE) granted by DOE.

Reviewer 3:
All the tasks are on schedule so far, but given the COVID-19 situation it may be somewhat delayed.

Reviewer 4:
The team has an extensive program and is meeting the milestones.

Reviewer 5:
Resources are sufficient, according to the reviewer.

Presentation Number: bat356
Presentation Title: Lithium-Ion Cell Manufacturing Using Directly Recycled Active Materials
Principal Investigator: Mike Slater (Farasis Energy)

Presenter

Mike Slater, Farasis Energy

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers indicated that the resources were sufficient, 20% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

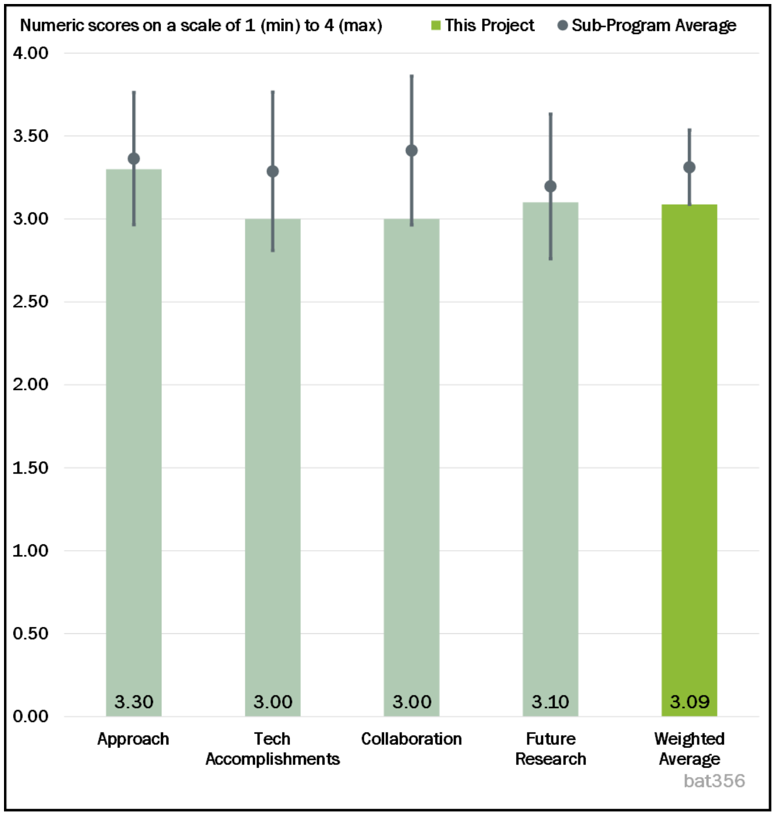

Figure 2-10 - Presentation Number: bat356 Presentation Title: Lithium-Ion Cell Manufacturing Using Directly Recycled Active Materials Principal Investigator: Mike Slater (Farasis Energy)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Researcher clearly identified the barriers in recycling Li-ion batteries and developed a well thought out technical plan to address it. The project is well designed to address all the technical barriers.

Reviewer 2:

The project is to build LIBs with directly recycling of active-electrode materials. This is supposed to be a cost-effective approach and therefore important as one of the problems in battery-materials recycling is the high expense.

Reviewer 3:

Direct recycling of active materials is the least energy and cost intensive approach to the recycling of LIBs. A careful evaluation of the feasibility of this approach is warranted. The project appears to be systematic in its design and feasibility. The delays are understandable and not cause for concern.

Reviewer 4:

The approach is to acquire materials from different sources, to separate the carbon and NMC, make new cells with recycled materials, and compare to cells with virgin material. It was not clear to the reviewer what the team is going to do when the cells with recycled material do not perform as well as cells with pristine material.

Reviewer 5:

The project appears to have been set up more like a proof-of-principle demonstration rather than a project to address specific technical barriers to cathode material supply and sustainability. The question—can NMC material be directly recycled into a battery with performance close to one built with virgin material—is not really the question;- most will readily believe that it can be done as a proof-of-principle (or already has been done). The project would have been better designed if it had directly addressed the key barriers to direct recycling of cathode materials: scalability of the separation and re-lithiation processes with cost-effective processing and the ability of that set of processes to handle variability in feedstock to support more than one commercial-use case (e.g., recycling scrap manufacturing of controlled, known composition). The project claims that it was designed to look at the feedstock variability question, but the work plan does not support that kind of assessment.

Similarly, although the project has been able to produce enough kilograms of material to support the first test cells, it was not clear to the reviewer if any of the project was really designed to examine scalability of the processes that are being used. This is surprising because one would think that the innovation that Farasis brings to the table is their separation and re-lithiation processes and that there would have been production targets for kilograms of material far in excess of what was needed for cell testing to demonstrate that the scalability barrier could be overcome. Instead, the project is well behind its original schedule, and although the cause was not specifically identified, it is probably safe to assume that the laboratory processes are not scaling well at the kilogram scale and the material is not pure enough and/or contains too many trace contaminants. In any case, the current plan would only be the very beginning of a well-designed plan to explore the effect of feedstock variability, which is a very large barrier to cathode-material sustainability via direct recycling.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project team has identified the complexity in the cell chemistry from recycled materials and developed a feasible recovery scale-up process, characterized the active material properties of NMC111, and compared them to pristine powdered materials to identify any variations.

Reviewer 2:
So far, the team has completed CB 1, and the testing results show inferior performance compared to cells built with pristine materials. However, the difference in capacity and FCE is within 15%. CB 2 was scheduled but delayed.

Reviewer 3:
The team has been working under a no-cost extension since January of 2019. The reviewer remarked that there was no explanation of why this program is so far behind, despite COVID-19. The team has test results from a first build that shows less performance from recycled material. There was no indication of how the team would change their processes to improve the performance. The project team is awaiting testing of its second cell build. No data were provided on the contribution from LBNL.

Reviewer 4:
Progress is being made although behind schedule (even before COVID-19). The drop in the reversible capacity of the cathode active material seems to potentially be a showstopper. More explanation obtained through experimentally driven studies is needed, according to the reviewer. Is this seen as inevitable or just a sign of the immaturity of the process? What is the mechanism?

Reviewer 5:
The reviewer commented that the project is clearly very far behind its original schedule, while the progress over the last year appears to be steady but unremarkable. The project will soon finish the second cell build and will probably have enough material from the module breakdown and recovery to build the third set of cells. The prospect of finishing in 6 months is not impossible, but any more delays will put that target in jeopardy.

The first-cell data were a significant accomplishment, according to the reviewer. The results were not surprising as they were very consistent with the underlying assumption that bulk NMC structure remains largely the same, but surface chemistry and aggregation changes affect performance versus virgin material. The results would have been better if there had been some data on the condition of the particles, their surface chemistry and aggregation, and the level of impurities and defects before and after the re-lithiation/reconstruction processes to show the effectiveness of such processes in recovering the performance of the virgin material.

Similarly, some data on the efficiency of the separation processes (mechanical and/or liquid separation) would have helped make the case that the direct processes would help to achieve sustainability in the cathode-material supply chain. The reviewer noted that recovery of less than 50% of the possible material may not support sustainability of NMC powders.

Finally, the material gap chart indicated that perhaps only 28% of recycled content may be possible in cathodes with recycled content due to low energy-capacity numbers. While not a particularly encouraging number, it was an important parameter to establish. It helps the credibility of the life-cycle analysis and techno-economic model for direct recycling to have a reasonably good idea how much recycled content can really be incorporated.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There is only one partner (LBNL) teaming with Farasis, and the level of collaboration and coordination appears to be very good (assuming that process scalability has been the issue in the delays and not getting the materials characterized at the National Laboratory). The contributions of the National Laboratory are obvious as the characterizations of the material are very necessary. In fact, one could argue that the project could benefit from more characterization data, particularly surface information, etc.

Reviewer 2:
The research collaboration with LBNL to leverage some of the testing resources from the Laboratory is a good strategy. Collaboration with a few more DOE National Laboratories and private industry would broaden and speed up the development process in addressing the difficulty in separating direct-recycled active materials.

Reviewer 3:
The project team has collaborated with LBNL for advanced chemical diagnostics and materials characterization. The reviewer remarked that this is important as it will help to understand the factors affecting the performance of the recycled batteries. However, there are no activities or results reported.

Reviewer 4:
Other than LBNL, the reviewer was not sure of any other partners. Farasis is a cell manufacturer so it already is a material supplier and source of aged batteries so the company must feel it does not need additional partners.

Reviewer 5:
The reviewer commented that it would have been helpful to see more precise examples of collaboration although there is only one external collaborator.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The project team has identified a clear path for future research in complete material recovery from module feedstock and relevant testing procedures.

Reviewer 2:
The reviewer said that the project is to be completed in the NCE period through June 2020, which clearly will be further delayed due to COVID-19.

Reviewer 3:
The team is going to collect material, build test cells #3, and measure their performance. The team does not explain how they intend to optimize the process of material recovery.

Reviewer 4:
The reviewer would have appreciated bringing in a greater mechanistic understanding regarding differences in the material performance. It seems that the UC-Berkeley collaborator would be able to help out with diagnostics. The project is near its end.

Reviewer 5:
The project is nearly complete (hopefully within 6 months) so there is not much latitude in the proposed future research. The second and third sets of test cells will be built and tested, and the results will be analyzed to demonstrate the potential value of the direct recycling processes. The final analysis should include (as promised) integrating the process model with electrochemical test data to quantify the impact of recycled materials on technology lifetime. The reviewed said that the raw battery-test data will not mean much by themselves.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Yes, the work is consistent with DOE efforts to develop a sustainable supply of cathode materials and other battery components to enable vehicle electrification. Determining the commercial potential for direct recycling is important and enables a comparison with the chemical-recycling approaches involving re-precipitation of the metal oxides from solution. Re-precipitation may be more favorable for a while as the feedstock changes with battery design changes (NMC111 to NMC532 to NMC811), but once the battery cathode technology stabilizes at low- or no-Co content, the comparative advantage of direct recycling rises—and it would support DOE goals to have the necessary direct- recycling processes in place and ready to scale.

Reviewer 2:
The reviewer stated that the project meets the overall DOE objectives.

Reviewer 3:
Building LIBs from recycled active materials potentially will reduce the cost and impact to the environment.

Reviewer 4:
Finding a way to collect and recycle the materials in LIBs is critical to a sustainable economy and keeping the price down.

Reviewer 5:
Recycling is critically important to create a sustainable and commercially viable electric car eco-system.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
According to the reviewer, the project appears to have sufficient resources remaining on the cost-share side of the balance sheet to complete the project in 6 months under a second NCE, assuming the pandemic disruption lessens.

Reviewer 2:
Sufficient resources are there for the researcher to address the barriers and technical accomplishments.

Reviewer 3:
The reviewer indicated that funding is at the appropriate scale for this project.

Reviewer 4:
The delay in achieving the stated milestones is not due to the funding insufficiency.

Reviewer 5:
This program is taking a much longer time than originally envisioned. One assumes that if more resources were dedicated to the project, work would be accelerated.

Presentation Number: bat357
Presentation Title: Thicker Cathode Coatings for Lithium-Ion Electric Vehicle Batteries
Principal Investigator: Stuart Hellring (PPG Industries)

Presenter

Stuart Hellring, PPG Industries

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

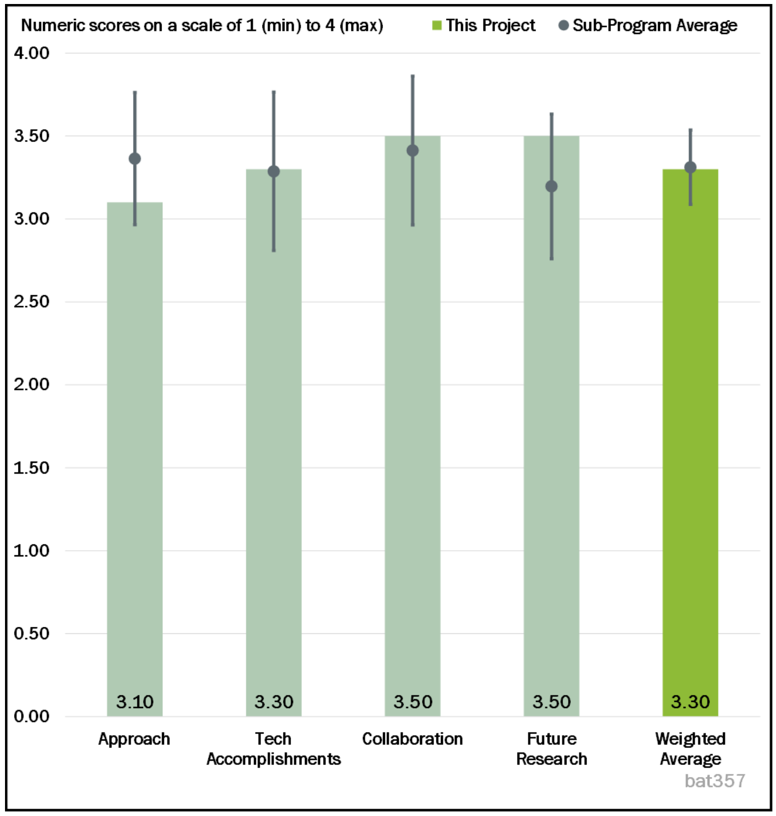

Figure 2-11 - Presentation Number: bat357 Presentation Title: Thicker Cathode Coatings for Lithium-Ion Electric Vehicle Batteries Principal Investigator: Stuart Hellring (PPG Industries)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project team has developed well thought out, relevant metrics and targets for anodes and cathodes to reduce the battery size, weight, and cost by using thicker coating technology. The reviewer praised the project as being very well designed with a feasible approach to address the barriers.

Reviewer 2:

The team's approach is using PPG binder for NMC622 with higher areal energy density and eliminating the toxic NMP in the cathode slurry. The reviewer noted that the approach works well as indicated by the performance tests.

Reviewer 3:

The overall approach is to develop a means of producing thick electrodes without the use of NMP. In general, the team will start by making electrodes of 20 mg/cm^2 and gradually advance to 40 mg/cm^2 cathode material. The reviewer remarked that the team does not explain the levers it has in improving its process. The presentation comes off as if the team has a formulation and it just has to go make the electrodes. The team mostly shows cycle performance in the accomplishments but little on how it made such progress.

Reviewer 4:

The project appears to have focused on the manufacturing of thick electrodes. While the approach taken to achieve this goal appear reasonable, there are additional barriers that may need to be addressed to enable the introduction of high loadings into automotive cells. Furthermore, there appears to be little discussion of the density of the electrodes. The reviewer's view was that just having high loadings alone is not sufficient to have a more attractive product.

Reviewer 5:
While the project (nearing its completion) appears to have produced some valuable results on non-NMP cathode binders and the production of thick electrodes (particularly cathodes), the reviewer was of the opinion that the project was only moderately well set up to address the barriers of thick electrodes and NMP use in battery manufacturing,. The need for thick anode development and pilot-plant production should probably have been anticipated, and a battery manufacturer or similar cell developer probably should have been recruited from the start. It appears that the Pennsylvania State University (Penn State) was recruited to help in the development and that the research focus in the final year had to be redirected toward this effort. While approved by the USABC sponsor, this could have been avoided in all likelihood.

Also, the two technical barriers being addressed are not necessarily coupled as the project plan implies. Once the team identified a suitable, safer, greener solvent to replace NMP solvent in cathode production of normal thickness electrodes (i.e., barrier #1), the reviewer indicated that the comparisons of the PPG binder to the NMP binder should have stopped there. While it is fine to promote the PPG binder for thicker electrodes, the comparison of performance of the thicker electrodes with PPG binder needs to be made with other advanced thick electrode fabrication methods, like semi-solid processing, rather than with the NMP process for thin electrodes. The barrier for thick electrodes exists primarily because cathode-preparation methods for thinner electrodes using NMP do not scale well to producing thicker electrodes. Also, the comparison for thick electrodes (1st batch) versus NMP binder were done at the University of Michigan Energy Institute (UMEI) facility, which may not have the best, most advanced technique for thick electrodes using NMP. Again, the barrier would have been better addressed with the involvement of a battery manufacturer and with comparisons of the PPG binder with other advanced, thick-electrode fabrication approaches or any commercial cell with the equivalent areal density regardless of how the cathode was prepared.

Finally, the other issue with thick electrodes (i.e., barrier #2) is that they have power limitations when cycled at a high rate, even when they can be formed into a pouch cell successfully. The project would have been better designed to address the thick-electrode barrier if some data at high charge/discharge rates had been planned. Cycling at C/3 is okay, but it does not tell the whole story on the ability to access all of the active material in a thick electrode.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Technical accomplishments are nicely formulated with a step-by-step approach. The project team characterized the baseline cathode performance with PPG binder to that of polyvinylidene difluoride (PVDF)-NMP binder and furthered with targeted cathode performances.

Reviewer 2:
The team has demonstrated that it can manufacture electrodes with high loadings and achieve reasonable cycle life at the C/3 rate. There appears to be knowledge gained in both new materials (binder-solvent systems) as well as manufacturing process.

Reviewer 3:
With PPG binder, the team's 22 mg/cm^2 loading NMC622 reached 91.5% capacity retention with 1C charge rate at 1,000 cycles, while the control cell with PVDF was at 84.7%. The team also achieved 80% retention at 500 cycles with 30 mg/cm^2 loading and 85% at 450 cycles with 40 mg/cm^2 loading (with C/3 charging rate).

Reviewer 4:
The project team's formulation appears better than the typical NMP-PVDF binder system. As the team moves to higher loadings, the peel strength reduces as does the cycle life. The reviewer commented that there is no explanation or hypothesis provided to explain these results. Thus, it is not clear how the team hopes to improve on either, other than through "modifications." The team shows that it can successfully coat 40 mg/cm^2 electrodes and matching anodes. The capacity fade is too high to meet the USABC goal of only 20% loss in 1,000 cycles.

Reviewer 5:
Again, promising results were obtained by the project so there will be some impact on battery technology. The PPG binder system looks like a promising alternative to NMP for cathode production, but without any specifics about the solvent (how much greener is it, etc.?), it is hard to predict the impact on addressing the NMP barrier. Also, there was no cost analysis (% savings or cost) or lifecycle analysis to ensure that the solvent has a lower environmental impact than NMP and is affordable. There were also no data on the manufacturing variability of the new solvent or process, so it was not clear to the reviewer if the data presented for the "normal" baseline cells represent a real breakthrough or not. The initial results are certainly encouraging for its replacement of NMP, but there would have to be a lot more data on the process collected to conclude that the NMP barrier to battery manufacturing is about to go away.

Similarly, the data on the thick-electrode production are encouraging, but the focus on only C/3 cycle data limits the enthusiasm. The thicker electrodes have a long way to go—calendar life testing, power measurements, abuse testing, gassing, DST, etc. The C/3 cycling results on the final set of cells will of course be an important first step when they are obtained, but there will be a lot more to do, much of which will probably require state-of-the-art battery manufacturing in lieu of lab-scale/pilot-scale production. The performance issue with thick electrodes is not just due to the shortcomings of the binder in fabrication.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that Involvement with academia, industry, and a DOE National Laboratory is a great way to address the technical barriers and speed up the development process

Reviewer 2:
PPG collaborated with a National Laboratory and universities, as well as other industrial companies in this project.

Reviewer 3:
It appeared to the reviewer that many hands from different organizations helped to make this work successful.

Reviewer 4:
The project team has a world-class material supplier, a group that appears good at making pouch cells, and a company willing to test the cells. It was not clear to the reviewer that the team or a partner is able to successfully identify the reason for the rapid capacity fade.

Reviewer 5:
It was not exactly clear to the reviewer how some of the contributors (UMEI, Penn State, and the Battery Innovation Center) were recruited and participated as part of the team, but PPG should be given some credit for stitching together a partner set that has gotten them to this point. In the end, they seem to have forged collaboration where they needed and gotten enough coordination to be ready for the final test cell build/test. However, a clearer, better plan for collaboration and coordination at the outset of the project might have shortened the timeline on this 3-year binder development process and allowed more extensive testing on the thickest electrode cells.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer remarked that the proposed future research is a continuation of the improvement process from the present research to address the technical barriers and gaps—a good strategy.

Reviewer 2:
The project is pretty much completed, according to the reviewer. The only task left is to deliver the final target cells (40 mg/cm^2 loading) for testing, which will depend on the COVID-19 situation.

Reviewer 3:
The project is nearing completion. There really is not much to do other than the planned final build/test with the thickest electrodes.

Reviewer 4:
Apparently, all that is left to do is to cycle the final cell deliverable.

Reviewer 5:
The reviewer said that the project is ending.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Generally, the project is well aligned with DOE objectives for vehicle electrification by addressing two challenges: reducing the widespread use of NMP solvent in cathode production and developing high areal density cathodes for longer range batteries in vehicles. The reviewer noted that the project has set the stage for further research and development to address these important challenges.

Reviewer 2:
The project presented research that meets all the DOE objectives.

Reviewer 3:
PPG has made cathodes with no toxic NMP in the binder, while achieving better performance and increased areal energy density.

Reviewer 4:
Making higher energy density cells is a high priority for the DOE. In this way, costs per kWh can be reduced.

Reviewer 5:
The reviewer suggested that future work should focus on achieving high energy density and fast charge (25 minutes [min.]) with high loading electrodes.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
It appeared to the reviewer that the project is meeting its deliverables and making reasonable progress.

Reviewer 2:
Resource allocations have been identified very well.

Reviewer 3:
The project will be completed shortly after pandemic restrictions are lifted, and the reviewer indicated that there appear to be enough resources left to complete this final amount of work in the next couple of months.

Reviewer 4:
The project is little delayed due to COVID-19.

Reviewer 5:
Resources are sufficient.

Presentation Number: bat359
Presentation Title: Status and Challenges of Electrode Materials for High-Energy Cells
Principal Investigator: Stanley Whittingham (Binghamton University)

Presenter

Stanley Whittingham, Binghamton University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

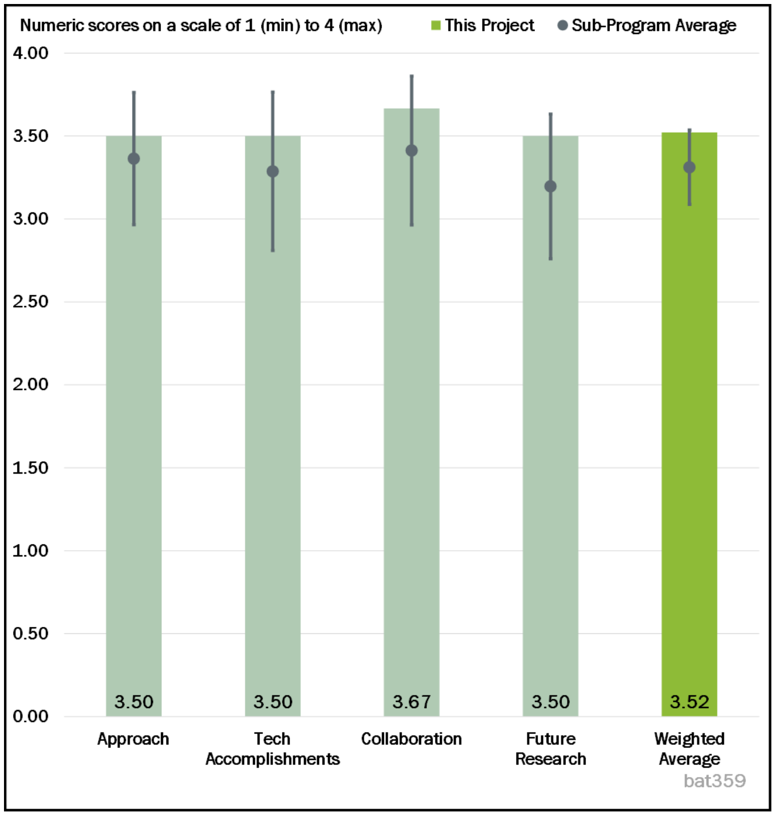

Figure 2-12 - Presentation Number: bat359 Presentation Title: Status and Challenges of Electrode Materials for High-Energy Cells Principal Investigator: Stanley Whittingham (Binghamton University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, the effort is well designed, feasible, and comprehensive. A clear scientific path toward overcoming obstacles for developing a cell that can deliver 500 Wh/kg was presented. Key issues such as cathode (high-Ni NMC) instability and safety are being addressed.

Reviewer 2:

The reviewer found the approach to improving the energy of high-Ni NMCs to be very good and commented that addressing irreversible capacity loss (ICL) and thermal stability are critical.

Reviewer 3:

The reviewer indicated that this presentation focused on one of the Keystone projects (Materials and Interfaces) in the Battery500 program, which has a goal of developing a Li-metal battery with either an NMC or a sulfur (S) positive electrode that can achieve 500 Wh/kg. This Keystone project is tasked with providing materials and chemistry support to other parts of the program, as well as to develop electrodes and find cell designs that will allow this goal to be achieved. Toward this end, this particular aspect of the work is directed toward coating NMC electrode materials to reduce reactivity in the environment and in the cell, understanding and mitigating first-cycle inefficiencies, and preparing high-capacity, high-Ni-content electrode materials that are not yet commercially available. The most challenging part of the project deals with addressing Li-metal cycling. While multi-faceted, the approach is highly focused and goal oriented.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented that the focused approach has resulted in considerable progress for the program as a whole, judging from the results shown on Slide 7, which are impressive. A simple way to gain some energy density is to address the first-cycle irreversibility. Results reported here show what factors affect this and point to kinetic limitations near the end-of-discharge as the culprit. This is in agreement with earlier work by Abraham at ANL. The next step is to figure out what to do to overcome this. It is worth taking a look at the literature to see what has already been done along these lines; for example, partial low-level substitution with titanium (Ti) seems to reduce the inefficiency in NMC442 materials. The same goes for coating electrodes, where a lot has already been done.

Reviewer 2:
Excellent progress has been achieved this period. The reviewer noted that the potential source of first-cycle capacity loss in high-Ni NMC was identified (slow Li-ion diffusion), and a niobium (Nb) coating was found to significantly minimize this issue, resulting in a 5% increase in energy density of the full cell.

Reviewer 3:
There are good results for the year. The reviewer was not completely convinced that poor Li diffusion near full lithiation of NMC is the cause of the higher ICL. The improvement of ICL with calendaring and coating of the NMC seems to hint at another source of the issue.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Professor Whittingham has always exemplified the best in terms of collaborative research, and he continues that here.

Reviewer 2:
The reviewer commented that a synergistic and productive collaboration exists between Binghamton University and the Battery500 team members, as evidenced by recent publications.

Reviewer 3:
The Battery500 program, including this project, is highly collaborative and draws upon expertise from various National Laboratories and academic institutions. It appears to be carefully coordinated among the various institutions and is very goal oriented. The reviewer's only criticism here would be that it may be good to coordinate with other DOE programs as well since there is some overlap here with other projects (e.g., reducing Co content in NMCs). There has been a fair amount of work already dedicated to understanding and mitigating first-cycle inefficiencies in NMCs as well as their thermal behavior (also there is much research on this done outside the United States). PIs in this program should check the literature carefully to make sure they are not inadvertently duplicating previous work but are instead extending it.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The planned work to reduce cobalt in nickel manganese cobalt aluminum (NMCA) and modify materials to increase energy density by addressing first-cycle inefficiencies and improving conductivities so that thicker electrodes can be used is sound. Likewise, it will be important to assess thermal stability of each modified material.

There has already been quite a lot of research on reducing cobalt, modifying NMCs to reduce first-cycle inefficiencies, and assessing thermal behavior of NMC-type materials in DOE-funded work, both past and present. The reviewer suggested that that work can and should be leveraged for this project.

Single-crystal materials may improve tap density and thus energy density, but it could come at the cost of rate capability (depending on size of crystal and whether modification to improve electronic conductivity is successful), so that is something to watch out for.

Reviewer 2:
The proposed research plans are methodical and address the major obstacles in developing a Li-metal battery. Efforts focus on pushing the limit of Ni content and reducing the concentration of Co. Plans also include developing thicker cathodes to increase specific energy and improving capacity retention.

Reviewer 3:
While there are good future plans, the reviewer thought that future work on high-Ni NMC will yield diminishing returns. The reviewer said that it is possible to get another 15%-20% energy at best; however, DOE has a "next gen cathodes" project that is concentrating on high-Ni NMCs. The reviewer wondered if there are other cathodes that the Battery500 could research (in addition to S, which is of course very high energy). This is not a comment specifically addressing Professor Whittingham's research or future plans, just something for the entire program to consider.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This effort is highly relevant to DOE's goal of advancing Li-metal based battery technology. The PI has considerable experience in the field. In addition to Binghamton University's present investigation, the PI brings valuable historical insight to the Battery500 Consortium.

Reviewer 2:
This work is highly relevant to the goals of the Battery500 program and that of DOE Vehicle Technologies Office (VTO) for EV batteries.

Reviewer 3:
The reviewer called the project highly relevant but indicated that the comment above about other cathode options also applies here.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project appeared to the reviewer to have sufficient resources to successfully meet the project objectives in a timely manner.

Reviewer 2:
The reviewer stated that resources are sufficient.

Reviewer 3:
Resources are sufficient.

Presentation Number: bat360
Presentation Title: Scale-Up Optimization and Characterization of High-Nickel Cathodes
Principal Investigator: Arumugam Manthiram (University of Texas at Austin)

Presenter

Arumugam Manthiram, University of Texas at Austin

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

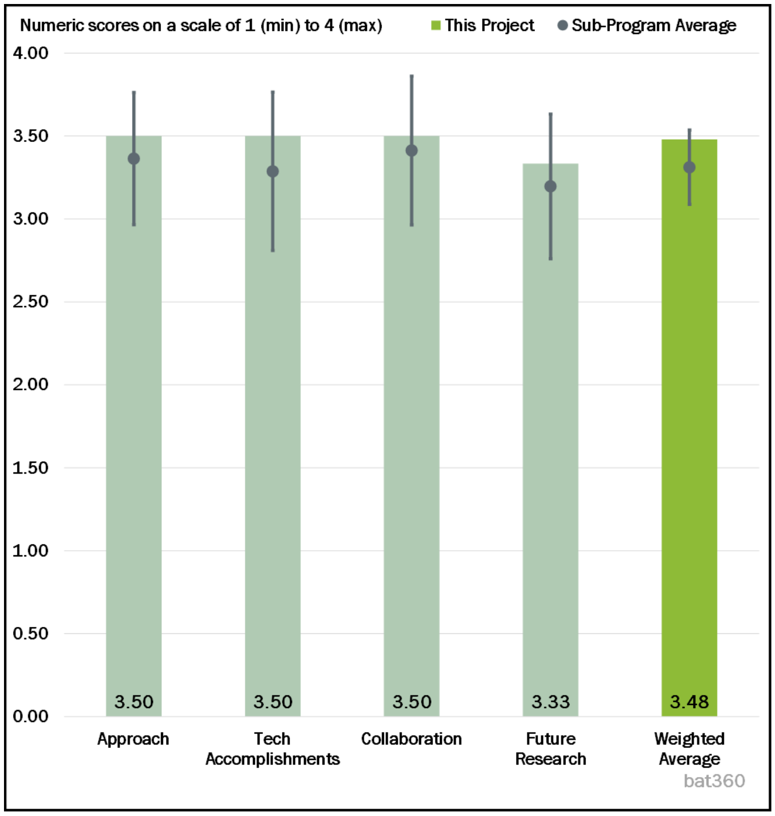

Figure 2-13 - Presentation Number: bat360 Presentation Title: Scale-Up Optimization and Characterization of High-Nickel Cathodes Principal Investigator: Arumugam Manthiram (University of Texas at Austin)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer called the combination of experimental work on anode (lithophilic framework) and high-Ni NMC excellent.

Reviewer 2:

The approach is well developed and addresses the fundamental issues confronting the development of a stable, high-energy cathode material.

Reviewer 3:

The approach for this part of the Battery500 program is focused on synthesis and scale-up of new materials with higher Ni contents than what is commercially available and on methods for enabling stable cycling of Li. There is some overlap with other DOE projects, such as the low-Co cathode one, where the focus is more or less the same (less Co results in higher Ni content in many cases). The reviewer stated that some work is also dedicated toward improving cyclability of Li, which is key to making the two chosen Battery500 systems work.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Progress here has been good. The PI observes that increasing Ni content in cathode materials comes with particular challenges, such as poorer cycling due to more pronounced phase changes, increased transition-metal dissolution, and particle cracking. Coating with polyaniline appears to alleviate some of these issues and improves cycling. The three-dimensional (3-D) lithiophilic framework on the anode side to allow more reliable Li cycling is an interesting idea and seems to show some promise. The PI will need to carefully assess the impact on energy density, according to the reviewer.

Reviewer 2:
Significant progress was achieved in the synthesis scale-up and characterization of high Ni-NMC cathodes, and the findings will help the Battery500 team move forward in their quest for a high specific energy cell. The major causes of cathode degradation were established by extensive experimentation (cell cycling) and the use of advanced characterization diagnostics.

Reviewer 3:
The reviewer asked why is the SEI growth shown on Slide 11 so non-linear? It looks like there is almost no change up to 500 cycles; then there is a huge change from 500 to 1,500. Also, the reviewer was confused about the milestones shown as completed on Slide 4 concerning Li-metal dendrite growth as the reviewer did not see any work presented there. Also, the second milestone concerning the impact of current density on Li-metal anodes is listed as completed, but this is also listed as a goal of future work on Slide 19.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer would like to see Professor Manthiram's team supply materials and possibly cells to other teams for independent evaluation.

Reviewer 2:
This project is part of the highly collaborative Battery500 program. This PI is tasked with providing new and promising materials to other PIs in the program although, as he states, scale-up is difficult for an academic laboratory. One possible solution is to utilize the Materials Engineering Research Facility (MERF) at ANL to do this; the reviewer's understanding is that there is no charge if the requester is from a National Laboratory or university. Likewise, scale-up could be contracted out to other facilities with pilot lines although there will likely be charges for this. While, in general, collaboration and coordination are very good in the Battery500 program, there are other efforts within DOE projects that may be relevant to this project (e.g., a low-Co cathode program) and PIs should do more to reach out to researchers in these programs.

Reviewer 3:
Productive collaboration exists between this project and other member's projects of the Battery500 team. This includes Brookhaven National Laboratory (BNL) (structural and morphological characterization of high-Ni NMC), Binghamton University (thermal stability studies), INL (electrochemical analysis), and PNNL (evaluation of electrolytes with cathodes).

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer particularly liked the Li-free cell work planned for 2021. This is the ultimate goal of cells using lithiated cathodes.

Reviewer 2:
Future work is devoted to further electrochemical characterization of cells containing Li anodes and high Ni-content cathodes, more work on the lithiophilic hosts for the anodes, use of electrolyte additives, and attempting "anode-free" cells. The plan seemed appropriate to the reviewer.

Reviewer 3:
The future planned activities are sound and are a logical extension of recent findings. They address the challenge of assessing the long-term stability of NMC cathode materials when using a full-cell design and an anode that has limited cycle life.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is highly relevant to DOE objectives. It is in line with the push toward higher cell specific energy and a reduction of costly raw materials, such as Co.

Reviewer 2:
This work is highly relevant to the goals of the Battery500 program and those of DOE-VTO with respect to electric vehicle batteries.

Reviewer 3:
The reviewer found the project to be highly relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
According to the reviewer, the project appears to have the necessary resources to complete the effort on schedule.

Reviewer 2:
There are appropriate resources.

Reviewer 3:
Resources are adequate. The reviewer suggested that the PI should reach out to MERF or other facilities for scale-up.

Presentation Number: bat361
Presentation Title: Understanding Electrode Interface Through Cryogenic Electron Microscopy
Principal Investigator: Yi Cui (Stanford University/SLAC)

Presenter

Yi Cui, Stanford University/SLAC

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

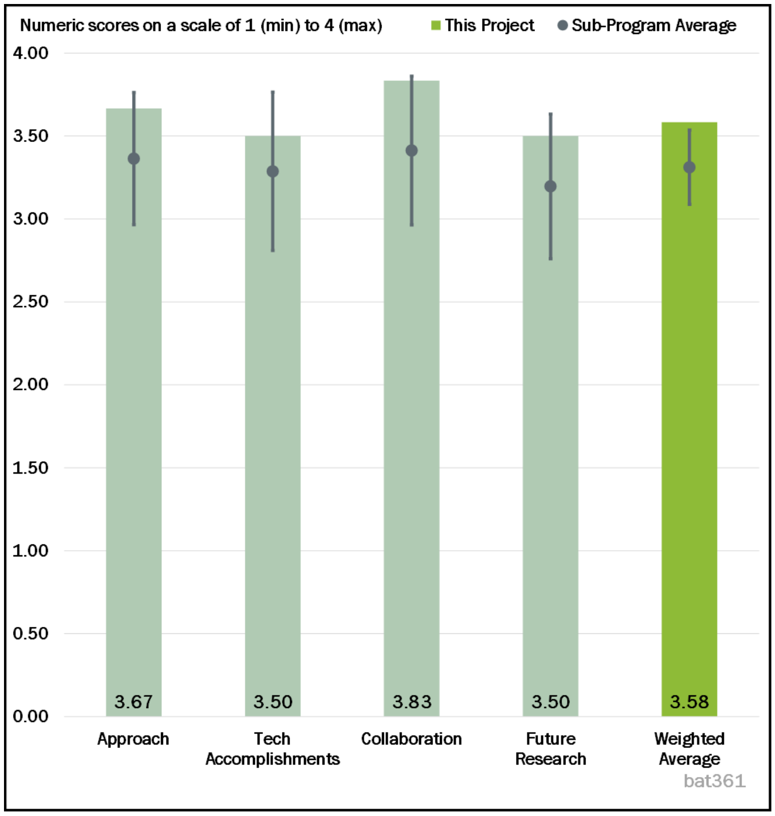

Figure 2-14 - Presentation Number: bat361 Presentation Title: Understanding Electrode Interface Through Cryogenic Electron Microscopy Principal Investigator: Yi Cui (Stanford University/SLAC)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer found the approach to be very imaginative and exploratory, just what is needed in a challenging and revolutionary program like Battery500.

Reviewer 2:

The project is well defined and very well coordinated with the rest of the Battery500 effort. The PI is very good and has done interesting work. Both the host structure data and the cryogenic electron microscopy (cryo-EM) data look promising and interesting.

Reviewer 3:

The team has an excellent approach in addressing the issues associated with the use of Li-metal anodes in high-energy battery cells. On the material design and synthesis side, 3-D Li-metal host composite anodes and interfacial- modification techniques are developed. On the characterization side, cryo-EM is used to investigate SEI on Li metal at atomic resolution. Together, the project effectively contributes to the goal of the Battery500 program in developing stable and high-capacity Li-metal anodes for high-energy batteries.

The reviewer indicated that one thing to consider is the relevance of cryogenic electron microscopic observation made under very low temperatures to what occurs in a practical cell operating under realistic cycling conditions.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Excellent progress was made here. The team designed and synthesized 3-D Li-metal composite anodes to accommodate volume expansion and contraction. The clear observation of SEI nanostructure under cryo-EM is rather impressive. The effect of the fluoroethylene carbonate (FEC) additive on the properties of SEI formed was elucidated, and the evolution of SEI was also investigated. The team was incredibly productive, with an impressive body of publications published in high-impact journals.

It was not clear to the reviewer how much of the cryo-EM studies were carried out in situ or in operando. There is a bit of dilemma here as, on one hand, SEI observation needs to be made in situ/in operando to be relevant but on the other hand, the low-temperature conditions under cryo-EM is likely to cause significant alteration in SEI behavior. The reviewer would like to get the team's opinion on this.

Reviewer 2:
The reviewer commented that the approach is somewhat difficult to evaluate as Professor Cui tends to show results from many years ago mixed in with his results from 2019, but still very good progress. One question that might be worth trying to answer is if the Li-metal SEI grows with time at a fixed potential. If it does, then it is clearly not passivating.

Reviewer 3:
The data looked very good to the reviewer. While the reviewer saw the connection between SEI structure and efficiency, the reviewer wondered how this information will be used to go from 95% to 99.9%. Has the PI looked at—or is planning to look at—the higher (99+% efficiency) that appears to be the focus among other PIs in Battery500? It will be good to look at the latest materials. The reviewer noticed that in the next talks that this is happening so maybe the project has a plan already in place.

The reviewer was a bit concerned about the sudden lower efficiency on the host structures. Please make sure this is not a soft short as this is possible. The reviewer worried that the host will lead to deposition at the surface (closest to the cathode) and lead to dendrites. The PIs should consider seeing what the charge rate limit is before dendrite formation and quantify this, which will really help the community. Also, the reviewer expressed worry that 3-D constant currents (CCs) with a liquid will add more surface area for more SEI formation and less efficiency.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration across the team in the Battery500 program and Stanford Linear Accelerator Center (SLAC)/Stanford University is excellent.

Reviewer 2:
This reviewer emphasized that the whole program is very well coordinated. The reviewer said that it was Impressive to see this in such a large program.

Reviewer 3:
There are very good collaborations.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Overall, the proposed future work is logical toward addressing the barriers in Li-metal based batteries.

Reviewer 2:
The reviewer liked all the tasks, which addressed the reviewer's previous questions.

Reviewer 3:
The reviewer wondered if a team in the Battery500 program should start to investigate in-situ dendrite diagnostics. There is yet to be an electrolyte, whether it is ceramic, polymer, block co-polymer, etc., that does not form dendrites under some conditions. The reviewer suspected that the car companies would be much more likely to use a technology like Li-metal cells if there were a way (using coulombic efficiency, for example) to detect the beginnings of dendrite formation and growth.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The use of Li-metal anode is an important step toward achieving the Battery500 goals. Current technology faces significant challenges in terms of low CE and poor cycling life of Li-metal anodes. By developing more efficient 3-D composite Li anodes and engineering a more stable SEI layer, this project is very relevant to the overall DOE objectives.

Reviewer 2:
The reviewer found the project to be highly relevant.

Reviewer 3:
According to the reviewer, Li-metal is very relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
It was unclear to the reviewer how much funding this project receives, so it was difficult to judge whether or not enough resources are available. However, the overall Battery500 program has sufficient resources.

Reviewer 2:
There are appropriate resources, according to the reviewer.

Reviewer 3:
The project has good use of funds.

Presentation Number: bat362
Presentation Title: Lithium-Metal Anodes: Problems and Multiple Solutions Based on Hosts, Interphase, and Electrolytes
Principal Investigator: Jason Zhang (Pacific Northwest National Laboratory)

Presenter

Jason Zhang, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

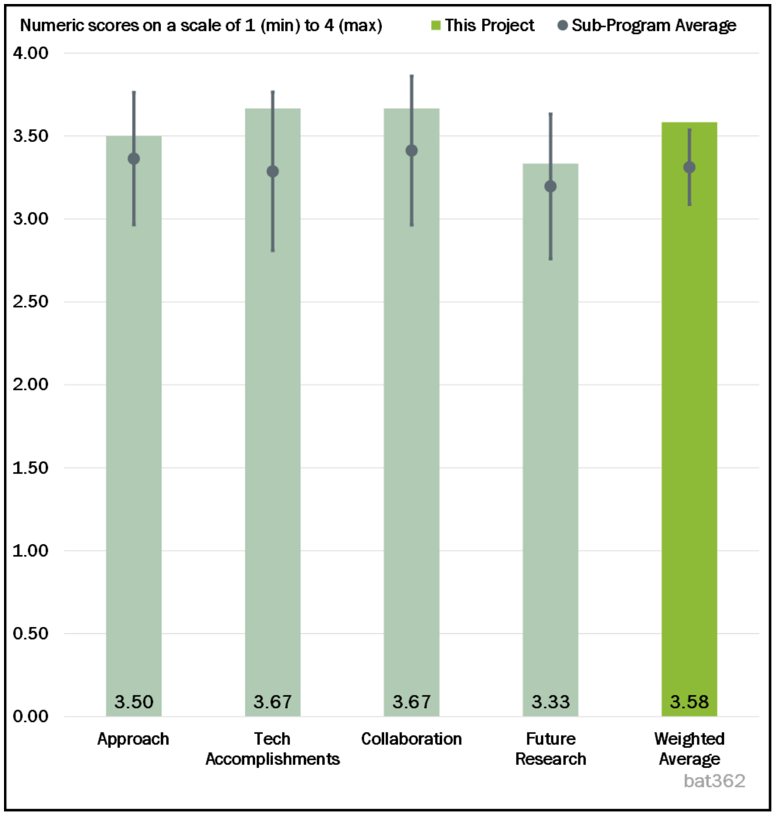

Figure 2-15 - Presentation Number: bat362 Presentation Title: Lithium-Metal Anodes: Problems and Multiple Solutions Based on Hosts, Interphase, and Electrolytes Principal Investigator: Jason Zhang (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project is sophisticated, comprehensive, and well designed. It focuses on shedding light on a major obstacle impeding the development of a high-energy-dense battery: the reactivity of Li metal with traditional electrolytes.

Reviewer 2:

The team proposed highly effective approaches to address the barriers. The team proposed innovative electrolytes, such as localized high-concentration electrolytes (LHCE), and 3-D lithiation hosts to mitigate poor CE and large volume change associated with Li-metal anodes.

Reviewer 3:

Novel electrolytes are almost certainly needed for Li metal. The reviewer wondered if there is a better way to screen them other than cycling. Perhaps leakage current can be monitored at a fixed potential or the thickness of the SEI as a function of time at a fixed potential can be measured to determine if the Li-metal SEI is stable.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The team's findings have significantly expanded the knowledge of ether-based electrolytes and have provided new perspectives of electrolyte design for LI-metal batteries. LHCEs were shown to have a high cycling efficiency (99.5%) in pouch cells.

Reviewer 2:
Using innovative LHCEs, the reviewer noted that the team made excellent progress to improve CE to 99.77% and reduced Li-volume change by four times in a full cell with a high-Ni NMC811 cathode. In addition, the team also demonstrated the feasibility of an anode-free Li rechargeable cell, albeit with limited cycles. Using innovative surface-characterization tools, such as cryo-EM, the team characterized the cathode-electrolyte interphase (CEI) and SEI compositions. These results should enable the team to improve the electrolytes to meet the Battery500 goals.

Reviewer 3:
Some of the results (Slide 14 with 1.5 mAh/cm^2 cathode and 10 mAh/cm^2 anode) are not representative of a commercial cell, but overall, it is well done. Also, one needs to remember that 99.3% CE means the cell with twice the excess Li is dead in 100 cycles or so. The reviewer said to be careful to keep the final goal in mind: 99.9% CE or higher.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The PI assembled an excellent team, with a clear description of the role of each team member.

Reviewer 2:
There has demonstrated significant and valuable collaboration with such organizations as Stanford University, Texas A&M University, University of Texas, and University of California at San Diego.

Reviewer 3:
There are very good collaborations. The reviewer proposed an independent evaluation of their LHCE costs and commented that, while there have been results for several years now, cost has not been discussed other than at a very high level.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future efforts continue with a well-designed, comprehensive plan. The team will continue to investigate new formulations of LHCEs to increase affordability and improve safety. Efforts will also be devoted to investigating the optimized electrolytes.

Reviewer 2:
The reviewer proposed an independent evaluation of their LHCE costs and commented that, while there have been results for several years now, cost has not been discussed other than at a very high level.

The project needs some way to quantitatively predict whether an electrolyte-anode combination will produce dendrites or not and they need to be detected early.

Reviewer 3:
The project is 70% completed, and the project team demonstrated feasibility of achieving high CE using Li-metal anodes. However, the cell parameters used in those high CE cells, such as the loading of ~1.5 mAh/cm^2 with excessive electrolyte at a slow rate of C/10 and excess Li metal, will not enable reaching the 500 Wh/kg goal. The reviewer commented that efforts should not be devoted to reducing the cost of electrolyte (as was proposed) until the team can demonstrate high CE in cells capable of more than 500 Wh/kg. The team also needs to provide calendar life and low-temperature data using the LHCE.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is highly relevant, according to the reviewer.

Reviewer 2:
This effort has developed knowledge that is useful in understanding and enabling the use of Li-metal in liquid-electrolyte systems. The knowledge gained could lead to a much higher energy density and consequently a lower cost per kilowatt-hour battery than today's state-of-the-art.

Reviewer 3:
The Li metal-based project is relevant for achieving high energy density required for the Battery500 program. However, in addition to CE, the team needs to address Li dendrites and interface issues associated with Li-metal anodes.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources appeared sufficient to the reviewer, who noted that considerable progress has been made.

Reviewer 2:
There are appropriate resources.

Reviewer 3:
Resources are sufficient, but it was not clear to the reviewer that, with the remaining 30% of funds, the team will be able to demonstrate high CE using 500 Wh/kg cell parameters in pouch cells, protection layers to mitigate Li dendrites, and 3-D hosts to mitigate the interface issues.

Presentation Number: bat364
Presentation Title: Surface Coating for High-Energy Cathode
Principal Investigator: Jihui Yang (University of Washington)

Presenter

Jihui Yang, University of Washington

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

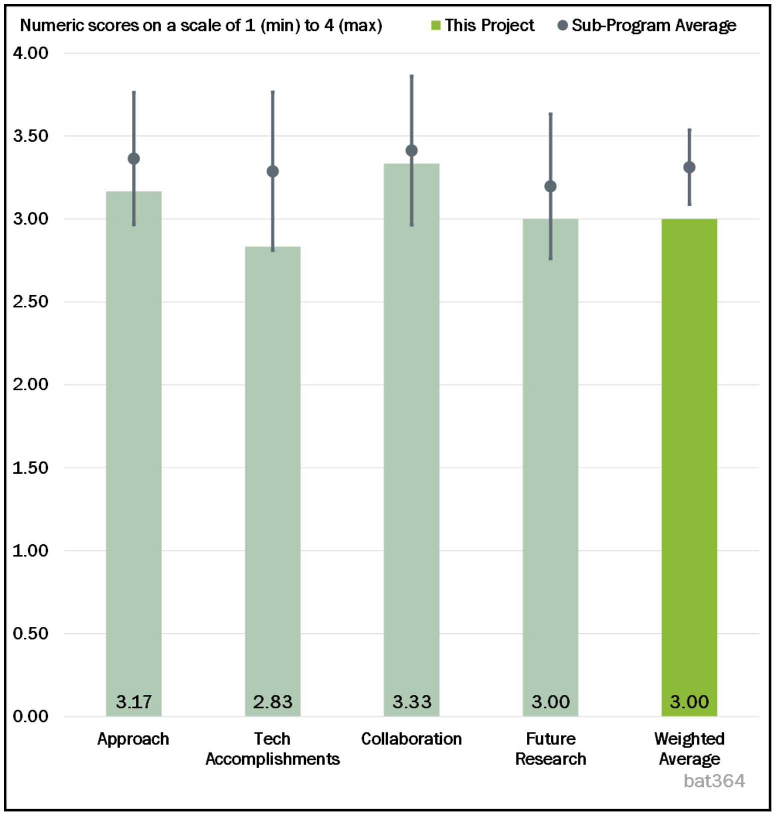

Figure 2-16 - Presentation Number: bat364 Presentation Title: Surface Coating for High-Energy Cathode Principal Investigator: Jihui Yang (University of Washington)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Work on this project is directed toward conductive coatings on Ni-rich NMCs and separators to ameliorate reactions with electrolytic solutions and to enable Li-metal cycling. This should enable cells with specific energies greater than 350 Wh/kg to be achieved, thus is worth pursuing.

Reviewer 2:

The lithium borate ($LiBO_2$)/LiF chemical coating approach for NMC 811 is a step in the right direction to improve stability at high oxidation voltage. The reviewer would like to know if the process can be scalable in principle.

Surface coating of separators with solid electrolytes, such as lithium aluminum titanium phosphate (LATP), is promising and has certain specific advantages. The reviewer wondered if this contributed to the increase in the interface resistance between the Li-metal and the separator, which could lead higher cell over-potential at high currents.

Doping NMC 811 with Al is a pretty good approach. Does the Al stay at the surface or occupy transition metal (TM) sites of the cathode? A few more doping levels should be tried to optimize the performance as only 1 mole% is shown.

Reviewer 3:

Coating and doping are very effective means to improve high Ni-cathode stability, but Al doping has been demonstrated by many for a while. It was not clear to the reviewer why this project is looking at this when others already have done it. Regarding the coating work, the reviewer really liked that the team used simple, wet-chemical means to coat the lithium diofluoro (oxalate) borate (LiDFOB). The reviewer was unsure why the project team is moving toward an expensive ALD technique and inquired about more cost-effective methods that can be scaled.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer wondered why there is only a very incremental improvement in the performance between coated versus uncoated NMC811 (see, for example, Slide 8). How significant is the reduction of polarization from coated versus uncoated? The basis for dq/dv peak comparison between coated and uncoated needs to be explained. How was peak position chosen to compare polarization difference?

The effect of Al doping on reduced cracking of NMC811 is clearly demonstrated. A mechanistic investigation is worthwhile.

How did the presenter know that $LiBO_2$ is shown from XPS on Slide 7? Only the B1s peak is shown. More information is needed to ascertain that it is $LiBO_2$.

Reviewer 2:
NMC-811 was coated with $LiBO_2$ and LiF by thermally decomposing LiDFOB. It was hard for the reviewer to tell the nature of the coating (e.g., whether it is conformal and pinhole-free) from the images that were provided. Nevertheless, the coatings did seem to result in some improvements although it is not clear why. In particular, it is not obvious why a coating would suppress the second hexagonal – third hexagonal phase transition at high potentials or improve its reversibility. It would be good to try to understand this.

The collaboration with Sun's group at Hanyang University on Al-substituted NMC811 also was fruitful; the substituted variant performed better and seemed to reduce cracking, which exacerbates fading. Another advantage to the Al-substitution may be better thermal stability although this was not explicitly addressed in the presentation. Coating separators with LATP also seemed to improve cycling. Again, it was not clear to the reviewer what exactly the mechanism is. LATP in contact with metallic Li is known to undergo reduction and becomes electronically conductive due to the presence of trivalent Ti. How big an effect this is and whether it is a problem will depend a lot on the thickness of the coating. There are plans to make the coatings thinner, and it is possible that problems will be revealed once this is done. In summary, modifications made to materials and cells all seem to have good effects, but the explanation of why is lacking. Understanding the mechanisms will help the PI refine the materials and processes to make them more effective.

Reviewer 3:
The reviewer was not sure what is novel here and suggested that the team try a bunch of coatings or a bunch of dopants, or work on why Al doping is effective.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This is part of the highly collaborative Battery500 program. It is good to see some collaboration outside this program (that with Sun at Hanyang University) as well.

Reviewer 2:
The group is collaborating with PNNL on cell fabrication and testing and University of Texas at Austin (UT-Austin) and State University of New York at Binghamton on synthesis and characterization of high-capacity NMC811 cathodes.

Reviewer 3:
There is good coordination to standardize protocols and data with the Battery500 team.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
ALD coating of NMC811 is relevant and provides a good basis for comparison with a chemical coating.

Reviewer 2:
Plans are to investigate methods to coat LATP on separators using ALD and spray coating and optimize the coatings. Coatings on the anode side may become electronically conductive more rapidly if thinner, however. It would be good to see some investigation into the mechanisms of how these coatings work, which can be part of the optimization.

Reviewer 3:
What is the team going to do with ALD that others are not already doing? Is the team able to do new chemistries or demonstrate scale-up? There are good results with the wet-chemistry method so why not work on low-cost methods to coat high-nickel materials?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This work is relevant to the goals of the Battery500 program, one of which is to enable usage of Ni-rich NMCs in high-energy batteries. These goals are also relevant to DOE-VTO objectives for electric vehicle batteries.

Reviewer 2:
Developing high-energy-density batteries with specific capacity in the range of 400 Wh/kg or beyond is key to DOE's electrification goal. This project is directed toward developing high-energy-density Li-ion cells.

Reviewer 3:
High-Ni cathode materials are a critical component to achieve DOE energy-density roadmap targets for automotive applications. The reviewer asserted that ways to achieve long cycle life and calendar life need to be found.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources are sufficient, according to the reviewer.

Reviewer 2:
Resources seem sufficient for this effort.

Reviewer 3:
There are adequate resources.

Presentation Number: bat365
Presentation Title: Stabilizing Lithium-Metal Anode by Interfacial Layer
Principal Investigator: Zhenan Bao (Stanford University/SLAC)

Presenter

Zhenan Bao, Stanford University/SLAC

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

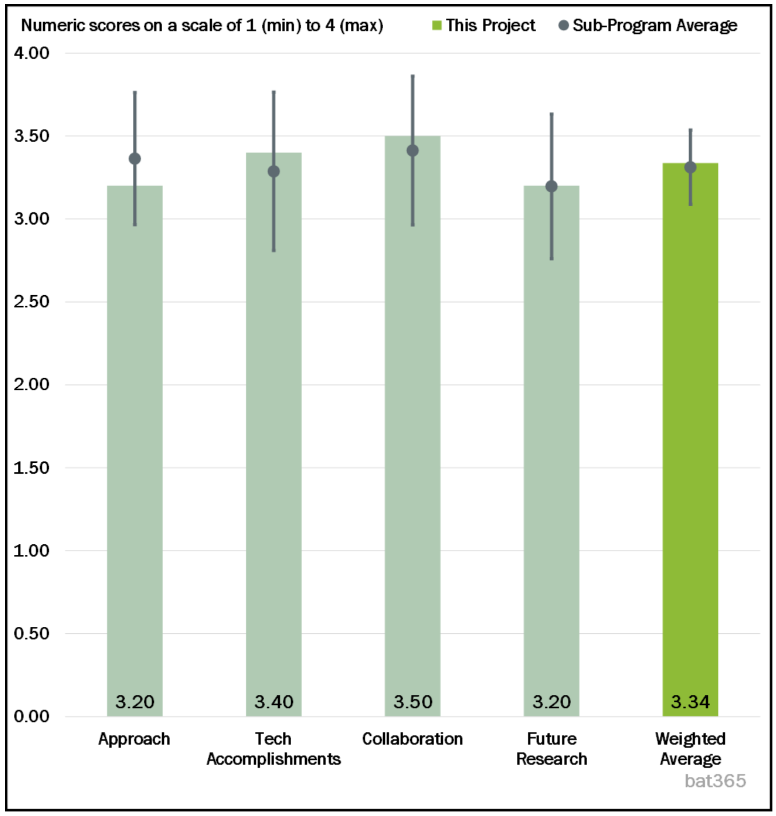

Figure 2-17 - Presentation Number: bat365 Presentation Title: Stabilizing Lithium-Metal Anode by Interfacial Layer Principal Investigator: Zhenan Bao (Stanford University/SLAC)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that the idea of adding polymeric layers with dynamic crosslinks to enable stable electrodeposition of Li is novel. The work covers diverse research activities ranging from polymer design to cell testing. The project is well designed and well planned.

Reviewer 2:

The reviewer understood the need to try all possible solutions to stabilize the Li-metal interface; thus, this project makes sense. An artificial SEI is very difficult to design, but so is every other solution. The reviewer thought that the focus has to be on first achieving a competitive CE and, somehow, convincing the team that a “soft” polymer will ever be able to stop dendrite formation and growth. Liquid electrolytes are certainly the most “flowable” and “conformable” electrolytes available, and yet they suffer dendrites.

According to the reviewer, this is an approach that can work. The Bluecar Li-metal batteries used by Bolleré have apparently lasted thousands of cycles with a polyethylene oxide (PEO) -based electrolyte due to pressure being applied to the cells. This might be a solution that could be understood in detail and designed into cells and modules.

Reviewer 3:

The use of a flowable polymer depending on the needs of the system is an important step of making Li-metal-based cells practical. The performance data shown are impressible, going out to 100-200 cycles. It would be more interesting to go to 1,000 cycles. How does the polymer affect energy density and retention?

Reviewer 4:
The overall approach is to use polymers with various desirable attributes as interfacial layers or electrolytes to enable higher efficiency and more stable Li-metal plating and stripping. A focus is to understand chemical and mechanical aspects of the polymer layer on the influence of Li-metal electrodes. The polymers are characterized using a variety of methods, and simulation and theory are used to more fully understand the mechanics of Li plating within these systems. The technical approach is sound and will continue to result in interesting science. A score of 3 was given instead of higher simply because it is unclear whether this is the absolute best strategy to enable Li metal batteries even though this reviewer found it to be a reasonable direction to pursue.

Reviewer 5:
Regarding battery life, the reviewer commented that improvements in cycle stability were demonstrated, but not a dramatic improvement. The team met the soft milestones of 20% enhanced cycle-life performance. The best performance shown in the slide was 250 cycles. The Stanford group only cycles enough to show improvement, so the reviewer did not know when or how the battery fails.

With regard to specific energy, 500 Wh/kg was stated as an objective, but specific energy was not determined for any of the cells evaluated.

Nonetheless, the reviewer indicated that about six different polymers were synthesized and tested as protective coatings at the Li-metal interface over the last 4 years. Different polymers were designed with clear hypotheses for how the properties were expected to improve the cycling performance. During the most recent year, work focused on the dynamic, single-ion network, polymers with different cation (Al, Si, and boron) and F substitutions. This was a creative development in polymer synthesis and determination of a unique combination of properties of a polymer electrolyte materials (flowable, near single ion, Li stable, solvent barrier) tunable with the cation and F substitutions.

Milestones also included investigation of 3-D host framework for the Li anode, but this was reported in a different presentation (BAT361). A number of the slides were identical for the two presentations, which confuses the assessment.

Milestones, which included adoption of the Battery500 protocols for Li architectures and quantifying the inactive Li, were listed in the slides. Results toward these milestones were not presented. Various researchers have advocated for using thin Li anodes to quickly and quantitatively determine the amount of Li lost due to physical isolation and electrolyte reaction to for SEI products. At first, the Li||Cu test cells suggested that this was being followed. Reading the procedures in publications, however, was quite confusing and a thick Li layer was likely deposited onto the Cu. So, the cause for sudden deterioration of the cells remains unclear, as is the relative amount of reacted Li versus physically isolated but unreacted Li metal, which was not determined.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
All milestones are completed or on track. There have been eight publications since the start of FY 2019, many in high-profile journals. The development of the aluminate salt for dynamic-bonding networks was interesting to the reviewer, and Li-metal results are promising, particularly the cycling. The reviewer also appreciated the nice combined experimental and simulation theory approach to understanding transport mechanisms. However, the interfacial resistances are quite large (approximately 700 ohms, assuming these are about 1 cm^2 electrodes) and conductivities quite low (10^{-4} Siemens [S]/cm at room temperature [RT]).

Reviewer 2:
There are several aspects to the proposed work: design of novel polymers with dynamic crosslinks, characterization of the polymer, application of the polymer to Li metal, and cell testing. The team has used

Battery500 protocols to test the efficacy of their materials, which is notable. The addition of modeling to the project is an excellent development. The PI presents considerable evidence that addition of the designed polymeric layers affects the morphology of deposited Li and cycle life. The differences in Li morphology seen by scanning electron microscopy (SEM) are striking. The reviewer hoped that, with time, the PIs will provide more direct evidence for the proposed hypotheses. The polymers appear to have functional groups that will likely react with Li metal, especially during prolonged cycling. Data of the kind presented on Slide 7 should be presented with error bars. The reviewer did, however, appreciate the error bars on Slide 8.

Reviewer 3:
Progress in designing, synthesizing, and evaluating the properties of novel polymer, Li-ion conductors is impressive. Unfortunately, in most cases the improvement in the cycling stability of the Li metal was modest. The investigators acknowledged the challenge posed to stabilize the Li metal and suggest that in future, combined approaches, polymer coating and a 3-D scaffold would be applied to see additional improvement.

The artificial SEI coatings captured most of the properties that are believed to be needed for a successful SEI. It was clear to the reviewer that, from the Li microstructures with distinct rounded particles of Li, the reaction with the electrolyte had not been well passivated. Additional interface area was created as the Li was plated and stripped.

Reviewer 4:
The PI explained the polymer-design principles and the basis for them very clearly. Progress was clear, but the reviewer was unsure how the modeling will impact further development of the polymer.

Reviewer 5:
The team reported 96.5% CE on Slide 16 so that is 60-70 cycles before a 2X Li is gone. The reviewer also suggested that the teams focus on one problem at a time (Li-metal SEI) instead of both that SEI and a 3-D host for Li.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The PI collaborates well with team members, especially at Stanford and the Stanford Synchrotron Radiation Light Source.

Reviewer 2:
There are many joint publications with other laboratories at Stanford and within the Battery500 project and very strong collaborations.

Reviewer 3:
The reviewer commented that the collaboration and coordination was very nicely integrated with the rest of the team and its goals.

Reviewer 4:
Collaborations are entirely with other investigators at SLAC. This has been productive and brought a wide range of modeling and characterization methods to the studies and publications. Collaboration with other Battery500 investigators seems to be missing, as they are not co-authors on any cited works.

Reviewer 5:
The reviewer was not sure how the collaborators worked together and who contributed what. The presentation came across as a single PI.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future work follows directly from the accomplishments described. It follows logically from prior work and is aimed at meeting overall programmatic needs.

Reviewer 2:
The PI showed how the results will be used in the further development of the polymer and what the remaining obstacles are. According to the reviewer, the PI's approach to the obstacles was well thought out.

Reviewer 3:
A reasonable continuation of work is conveyed although only briefly.

Reviewer 4:
Future work is directed toward further development of artificial SEIs, but it is vague and specifics were not given. Presumably, the plan is to further design and synthesize polymer coatings to act as SEI layers on the Li. The polymers synthesized to date have novel properties so additional work in this direction may be fruitful. It only takes one new material to change the future of Li-metal batteries.

Additional plans are to combine these artificial SEIs with 3-D Li host and high-performance electrolytes. Without further explanation, the reviewer remarked that there is an assumption that the expectation is for the improvements to be additive.

Reviewer 5:
As noted above, the reviewer would possibly de-emphasize the 3-D host work here as other teams are pursuing that. Instead, focus on achieving a competitive CE and, somehow, convincing the team that a "soft" polymer will ever be able to stop dendrite formation and growth, or consider some other way to control dendrites.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer enthused, "Absolutely!" Solutions to the Li deposition (dendrite formation) are critically needed for the project to succeed.

Reviewer 2:
Enabling Li-metal electrodes is a key target of DOE efforts right now. This work is clearly relevant toward that goal.

Reviewer 3:
The project is highly relevant to stabilizing the Li-metal interface.

Reviewer 4:
An important objective of the DOE program is to enable high-specific-energy rechargeable batteries; enabling Li metal is the most promising approach for meeting this objective. The work of the PI is clearly aimed at meeting this objective.

Reviewer 5:
This is relevant to finding a practical way to stabilize the Li metal within the liquid-electrolyte battery design.

If the artificial SEI coatings were more robust, they might have found a solution to a profound challenge for achieving Li-metal batteries.

There was a good effort and modest improvement.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The work reported here and in the cited publications was thorough and detailed.

The VTO support was coordinated with National Science Foundation programs lead by other Stanford co-authors.

Reviewer 2:
Resources are sufficient to meet milestones in a timely fashion.

Reviewer 3:
The resources applied to the problem at hand seemed to be reasonable.

Reviewer 4:
According to the reviewer, there are appropriate resources.

Reviewer 5:
It was not entirely clear to the reviewer how much funding is directed toward this specific project within Battery500, but it appears sufficient given the outcomes.

Presentation Number: bat366
Presentation Title: Advanced Imaging and Quantitative Characterization of Lithium-Metal Anode and Its Solid Electrolyte Interphase (SEI)
Principal Investigator: Shirley Meng (University of California at San Diego)

Presenter

Shirley Meng, University of California at San Diego

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

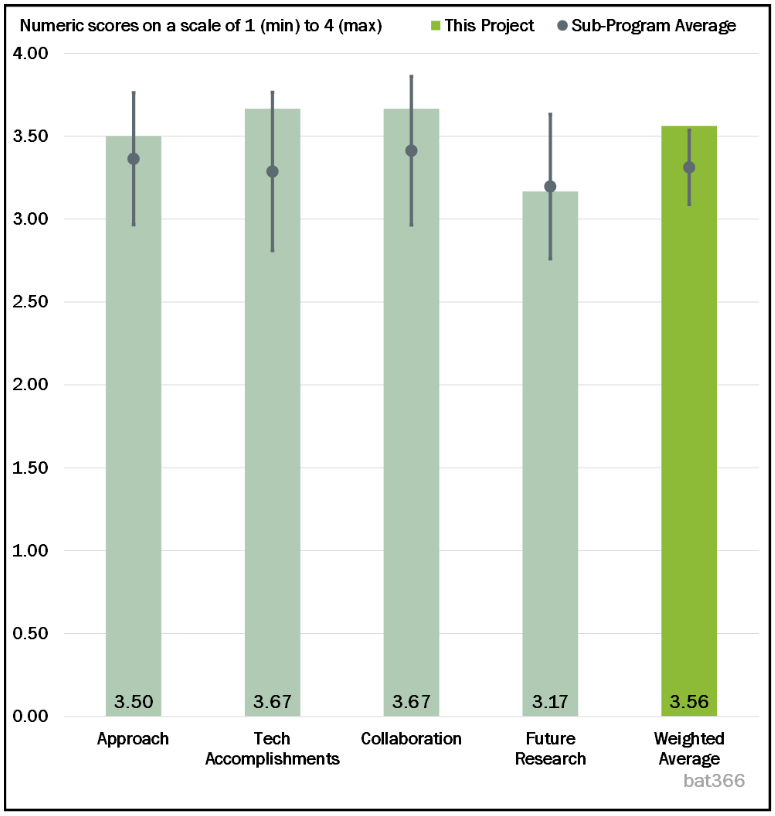

Figure 2-18 - Presentation Number: bat366 Presentation Title: Advanced Imaging and Quantitative Characterization of Lithium-Metal Anode and Its Solid Electrolyte Interphase (SEI) Principal Investigator: Shirley Meng (University of California at San Diego)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, the PI and team have provided extraordinary diagnostic support to the Battery500 team toward a mechanistic understanding of the Li-metal nucleation and growth and the SEI formation. Several state-of-the art techniques, such as cryogenic transmission electron microscopy (cryo-TEM), titration gas chromatography, and X-ray micro-computerized tomography (CT), are used for characterizing Li metal.

Reviewer 2:

The approach of this project is to combine microscopy, tomography, diffraction, molecular dynamics (MD) simulations, and quantitative measures of Li plating and stripping to understand the Li-metal SEI and its influence on performance. The reviewer found the approach to be systematic and well executed, among the best studies on Li-metal stripping and plating.

Reviewer 3:

The main challenge in the Battery500 effort is the stability of the Li metal. This approach directly addresses the understanding of the Li-degradation processes. Also, 3-D electrode for Li is proposed as a solution. The main diagnostic tool is cryo-EM. The reviewer was unsure if the program needs multiple people using this tool.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer noted that all milestones have been completed or are on track, and there are four publications, with two more submitted or in preparation, including in *Nature*. The studies are exhaustive, with new insights into Li-metal nucleation, a key account of dead Li and its influence on coulombic efficiencies in a variety of electrolytes, and initial promising studies on 3-D electrodes. This is an impressive amount of high-quality work that provides a deep understanding for the rest of the field.

Reviewer 2:
Evolution of Li-metal morphology and the SEI is pretty much coupled and to a large extent dictates the performance and cycle life. The PI and team have developed several strategies to mitigate dead Li-metal formation, but the focus of this work is developing various methods to characterize Li-metal and CEI to study their composition and morphology during stripping and plating. The team has demonstrated excellent progress in achieving its objectives, and the reviewer indicated that the results will lead to improvements in the CE and cycle life of high energy-density LIBs.

The reviewer was interested to know if the 3-D current collector approach can be scalable and, if so, what the fabrication methods are. MD simulation of Li-metal nucleation and comparison with cryo-TEM is a robust approach. Developing a multi-scale modeling effort for the 3-D current collector to map the heterogeneity of current distribution and electric field would be a good approach to validate X-ray CT results.

Reviewer 3:
The PI has a long history of excellent work, combining multiple tools to understand phenomena. The PI has some unique cryo-EM results and insights. The reviewer also liked the 3-D electrode studies. The reviewer was not sure the overall concept will be the answer for moving forward, but it is interesting. The 3-D electrode effort would benefit greatly from some electrochemical engineering modeling.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer was very impressed with the collaborative nature of all Battery500 projects, including this one.

Reviewer 2:
The PI has established a number of valuable constructive collaborations.

Reviewer 3:
According to the reviewer, there is a very balanced team and collaboration between the characterization team to help the cell assembly and the cathode development team to achieve the energy density and cycle-life targets.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed work looks promising and, if successful, would provide breakthroughs in making the Li-metal stable in liquid electrolytes and better control of SEI.

Reviewer 2:
The project is a reasonable extension of current work although only briefly highlighted.

Reviewer 3:
The PI is planning to continue current efforts. There are not a lot of details.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer stated that the work supports the Battery500 goal of approaching 500 Wh/kg for 1,000 cycles. To achieve this target requires stabilization of Li-metal. A mechanistic understanding of the evolution of Li-metal morphology upon cycling is critical for optimal CE and cycle life for EVs.

Reviewer 2:
The PI is attacking the crucial programmatic challenge, which should significantly reduce the cost of batteries if successful.

Reviewer 3:
Enabling Li-metal electrodes is a key DOE-VTO goal, and this project directly supports that mission.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer indicated that the PI seems to have sufficient resources.

Reviewer 2:
Resources are adequate.

Reviewer 3:
The resources appear sufficient given the outcomes although it was not clear to the reviewer how much Battery500 funding went directly to this project.

Presentation Number: bat367
Presentation Title: Characterization Studies on Li-Metal Anode and High-Ni Cathode Materials
Principal Investigator: Peter Khalifah (Brookhaven National Laboratory)

Presenter

Peter Khalifah, Brookhaven National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

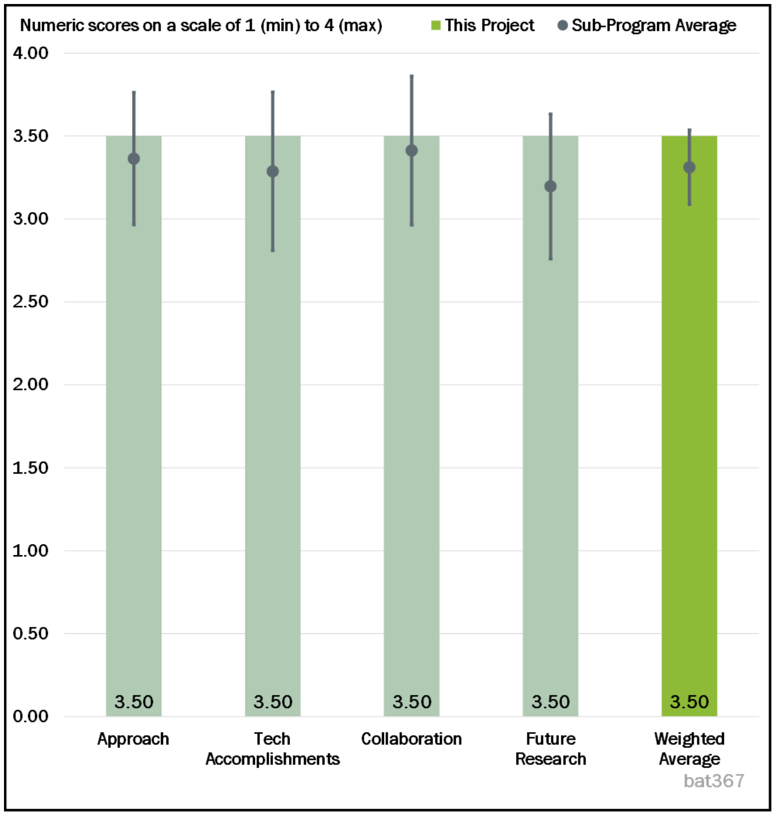

Figure 2-19 - Presentation Number: bat367 Presentation Title: Characterization Studies on Li-Metal Anode and High-Ni Cathode Materials Principal Investigator: Peter Khalifah (Brookhaven National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The multi-scale and multi-dimensional techniques used and developed for the project (e.g., in situ and ex situ X-ray diffraction [XRD], pair-distribution function [PDF] TEM, and transmission X-ray microscopy are powerful tools to help achieve the Battery500 goals.

Reviewer 2:

The reviewer called this extremely high-quality work to characterize cathode materials, including heterogeneity.

The reviewer asked why the focus is on gravimetric energy density when volumetric energy density is more important for vehicles.

The reviewer saw no reference to working on Li-metal batteries although it is one of the main project objectives.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

These are outstanding technological and modeling developments. The reviewer wanted to know if the effect of large pores or regions of especially low porosity can be correlated with failure caused by local over-potentials.

Reviewer 2:
All are either completed or on schedule.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer found a broad array of highly qualified scientists with many areas of expertise on this project.

Reviewer 2:
It was unclear to the reviewer how the ex situ and in situ measurement results are being used by collaborators to improve the performance and durability of NMCs and sulfur electrodes. For example, how do collaborators use the "hot spots" (Slide 10) and cracking (Slide 12) observations to improve the electrode and the NMC particles?

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The future directions are spelled out with some detail, not so common among the presentations that the reviewer has judged.

Reviewer 2:
The reviewer asserted that the single-particle-level measurements for mapping local strain and fracture should be carried out as a function of the cycle number, especially since a recent publication suggested that mechanical damages could occur in NMC particles during the first few cycles. See, for example, Dang, D., et al. (2019). "Fracture Behavior of Single LiNi0.33Mn0.33Co0.33O2 Particles Studied by Flat Punch Indentation." *JES* 166(13): A2749-A2751.

These measurements should also be carried out within each cycle since the strain distribution during lithiation is different from that during delithiation. The strain measurements should be compared with modeling predictions.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Yes, the characterization tools are critical to help achieve the Battery500 objectives.

Reviewer 2:
The reviewer asserted that the project would be more relevant if the goal included a volumetric energy density. Do Li-S batteries provide good volumetric energy density?

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
There are excellent in situ and ex situ characterization capabilities.

Reviewer 2:
The best facilities in the country are available to this project.

Presentation Number: bat368
Presentation Title: Battery500 Integrated Cell Diagnostics and Modeling to Identify Critical Gaps in Achieving High Cycle Life
Principal Investigator: Eric Dufek (Idaho National Laboratory)

Presenter

Eric Dufek, Idaho National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 33% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

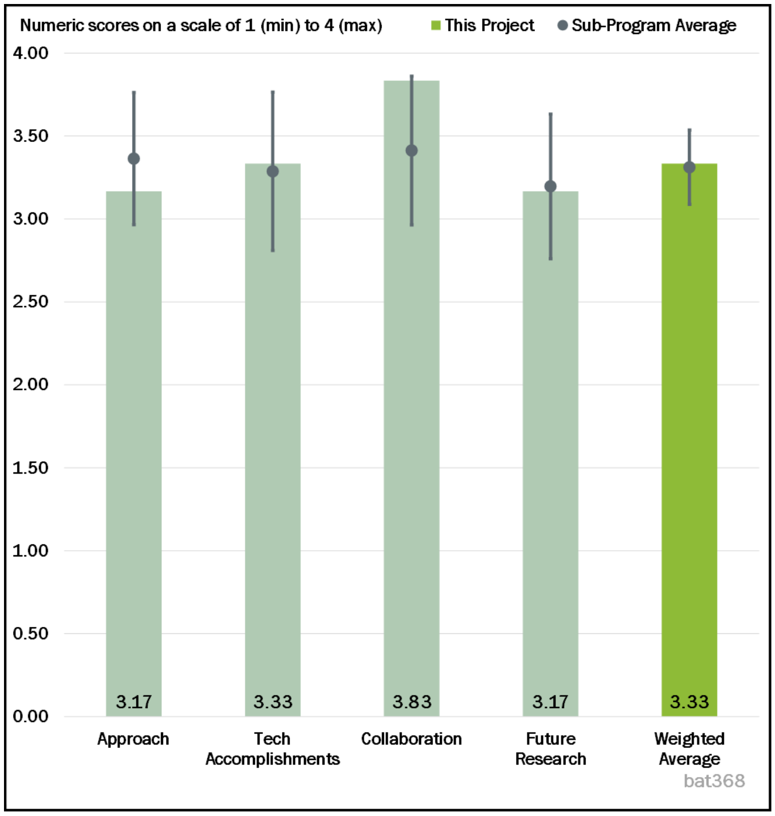

Figure 2-20 - Presentation Number: bat368 Presentation Title: Battery500 Integrated Cell Diagnostics and Modeling to Identify Critical Gaps in Achieving High Cycle Life Principal Investigator: Eric Dufek (Idaho National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the technical barriers are suitably addressed with proactively developed solutions to mitigate the challenges.

The project is appropriately designed with sound scientific approaches and technical methods for completing the tasks.

Reviewer 2:

The INL team developed a failure diagnostic to separate thermodynamic from kinetic-capacity decay, which is critical for cell design and cell-performance enhancement.

The project is well designed. The electrochemical-analytic-diagnosis method was published in *JES* and applied to Li-metal batteries (LMBs).

Reviewer 3:

The reviewer asserted that there is no specific approach provided for the plan to understand the failure modes of Li-NMC and Li-S.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Excellent progress has been made with significant results, including major findings and developments that could mitigate the technical barriers.

Reviewer 2:
The developed electrochemical analytic diagnosis has been applied to analyze the failure mechanism of LMB. Additionally, the spatial mapping of the cycled S electrode is important to understand the reaction kinetics of Li-S cells. Further, the reaction resistance can be obtained from electrochemical impedance spectroscopy (EIS) measurement and can be used to validate the kinetic resistance obtained from analytic diagnosis.

Reviewer 3:
This reviewer commented that cycling performance of cells cycled at two locations with different rates of capacity fade are shown without an explanation. Despite cells looking very similar during the first reference-performance test, they cycle very differently, without an explanation. The reviewer added that voltage relaxation shows how the impedance is only rising at the end of discharge and is limiting the intercalation of Li into the material, what the project team refers to as "cell kinetic imbalance," without a real explanation of the source of the impedance.

Poor performance of Li-NMC cells is shown along with predictions of life where the number of cycles is under 50. Additionally, there is no explanation why the change in pressure with voltage is so much more dramatic for the first cycle than for later cycles when it appears to follow the capacity variation of the cathode with voltage. The reviewer also noted that the presence of S-O species in a cycled S electrode is shown without providing an explanation of where it might be coming from. Further, there is a claim that "kinetics and wetting" are interrelated and explain poor performance of poorly wetting sulfur structures.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration and communication across the Battery500 project teams are outstanding and will significantly enhance the success of the program, in the reviewer's view.

Reviewer 2:
The INL team is closely collaborating with core Battery500 teams and seeding Battery500 teams and graduate research associates at North Carolina State University and Princeton University.

Reviewer 3:
The reviewer noted that the team made a point of showing where different National Laboratories made different contributions to the understanding of performance issues.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer stated that the proposed future research clearly identifies the project risks and impacts to the proposed approaches to mitigate these risks.

Reviewer 2:
The future work will focus on electrochemical and mechanical interaction, which is critical for LMBs. The potential challenges are addressed.

Reviewer 3:
According to the reviewer, there is no specific plan laid out for future work as opposed to a long list of things the team still needs to get to.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer noted that developing low-cost and high-energy-density batteries clearly meets the DOE objectives of reducing the cost of EV batteries while simultaneously improving the EV battery performance to make EVs affordable to all people.

Reviewer 2:
This project supports the overall DOE objective of developing 500 Wh/kg batteries.

Reviewer 3:
DOE's objective is to push the limit of battery energy density. The reviewer indicated that this project is looking at chemistries that can get to high energy density but either do not or do not cycle well.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project has sufficient resource to meet the milestone in timely fashion.

Reviewer 2:
INL has sufficient resources to achieve the stated milestones in time.

Reviewer 3:
This project, like all projects these days, lists the entire budget of the program so the reviewer was left to assume that all of the money must be going to this group. The team is making little progress for $10 million a year. In future years, the reviewer would appreciate an explanation that the team did not get the entire $10 million and let reviewers know which fraction of the $10 million was spent on this part of the effort.

Presentation Number: bat369
Presentation Title: High-Energy Rechargeable Lithium-Metal Cells: Fabrication and Integration
Principal Investigator: Jie Xiao (Pacific Northwest National Laboratory)

Presenter

Jie Xiao, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 20% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

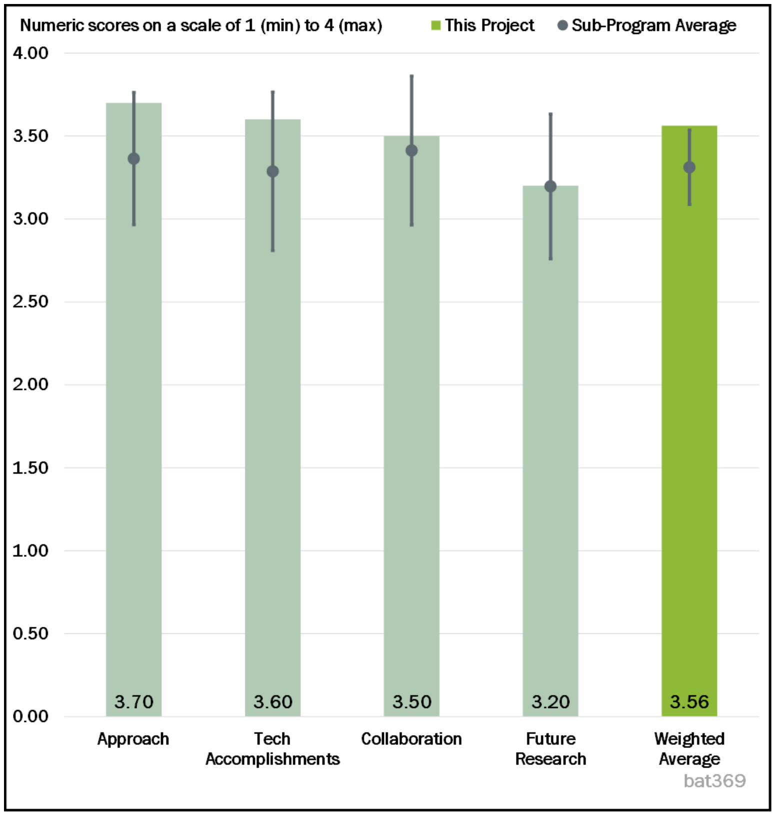

Figure 2-21 - Presentation Number: bat369 Presentation Title: High-Energy Rechargeable Lithium-Metal Cells: Fabrication and Integration Principal Investigator: Jie Xiao (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The technical barriers for developing high-energy Li cells are very well addressed. The dual approaches in developing Li -S and Li-NMC can potentially lead to the development of a low-cost Li-S cell that does not require the use of strategic metal in short supply, such as Co. The project objectives are well defined and the proposed technical approaches are feasible, according to the reviewer.

Reviewer 2:

The key factors limiting the performance of Li-S cells were identified. A safety protocol for studying high-energy Li- metal cells was developed.

Reviewer 3:

This project addresses the problem of capacity and energy stability with cycling. As such, the project’s outcome is important for the overall success of Battery500. The team showed that electrolyte consumption is one component limiting life in a Li-S cell, most likely due to reactions of the electrolyte with Li. Adding more electrolyte increases life, the reviewer offered, probably by having enough electrolyte to react with Li metal to form a “stable” passivating layer and still have sufficient electrolyte for good cell performance.

Reviewer 4:

The focus is on the proper barriers, and the approach is leading to improved batteries. The reviewer asked why the team is focusing on gravimetric energy density when volumetric energy density is more important for vehicles.

Reviewer 5:
The reviewer indicated that the team has things it wants to accomplish, but an approach to achieving these milestones is not discussed on the Approach slide. As one goes through the technical accomplishments, there is mention of the final result of its work but not the approach or the details of how the accomplishment was achieved.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer said that the project has made great progress toward a DOE Battery500 goal of high energy battery with 500 Wh/kg:

- Demonstrated Li-S cells with an energy density of approximately 313 Wh/kg but with limited cycle life that will needs to be optimized
- Developed Li-NMC cells with high energy density of 350Wh/kg and cycle life of 350
- Demonstrated 400Wh/Kg Li-NMC811 cell with limited cycle life of 50.

Reviewer 2:
The reviewer noted that 350 Wh/kg Li-NMC622 pouch cells achieved more than 350 stable cycles with 90% capacity retention. Additionally, 400 Wh/kg Li-NMC811 pouch cells achieved more than 50 cycles with 94% capacity retention. The correlation between cell-pressure change and electrode decay is critical to understand the capacity-decay mechanism.

Reviewer 3:
The reviewer posed a question about supposing the aim was 300 Wh/kg instead of 350. This is already much better than anything that is available commercially and would be highly valuable. How many cycles at what C levels could be achieved at 300? Industry would be very excited if the team can get that.

Great progress is demonstrated for NMC pouch cells although it was not clear to the reviewer exactly how this was done. Correlating pressure change with dead Li would be great, if it works.

Reviewer 4:
Progress in this project is very good. The team's progress has shown stable cell performance at 350 Wh/kg, with indications of similar stability at the 400 Wh/kg level.

Reviewer 5:
The team makes a claim that the cycling stability is a function of the amount of electrolyte by showing the results of adding more electrolyte. The reviewer's response was that there is no theory put forth as to why more electrolyte results in better cycle life but not higher capacity per gram of S. The team claims that the polysulfides react with the electrolyte, but does not describe the reactions as chemical, reductive, or oxidative. The project team provides little evidence for this claim. If the electrolyte reacted with the polysulfides, the reviewer questioned whether the capacity of the cell would decrease with time as these reactions proceeded. Because the polysulfides are solubilized, there would be no reason for the reactions to stop unless they reached an equilibrium state and an increase in electrolyte would result in more polysulfides being consumed.

Because more electrolyte helps with cycling, the team wants to make more room for electrolyte by reducing the binder content. The reviewer observed that the team also wants to reduce the porosity, which seems to go against a higher electrolyte concentration. It would be nice to hear the hypothesis on why more electrolyte helps.

The team shows cycling data of NMC 622 and NMC811 and that 350 Wh/kg and 400 Wh/kg can be achieved. There is no explanation about the challenges that had to be overcome to get to this point and what the team did.

The team shows a graph of yearly progress in cyclability, with very few details other than through the modifications of the electrode, the electrolyte, and cell design. What is the reviewer to take from that?

The team developed a test fixture to measure the pressure of the cell with cycling. The final pressure gradually increases with charge and is constant on discharge. The team hypothesized that this is caused by the formation of dead Li. If the Li is dead, the reviewer questioned if it had been present on charge and discharge. In the end, the reviewer noted the progress in cell fabrication, but stated that very little detail on how was provided.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
With regular interchange in ideas and frequent meetings, the collaboration and coordination across project teams are excellent.

Reviewer 2:
Jie Xiao's team has closely collaborated with three companies, nine universities, and three National Laboratories.

Reviewer 3:
There was ample evidence that the collaborators are working as a cohesive team. The contributions from each member were clearly spelled out.

Reviewer 4:
The reviewer found a ton of coordination.

Reviewer 5:
There was good collaboration across the laboratories.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed work is well thought out and focused on the overall project goal.

Reviewer 2:
Jie Xiao's team identified the challenges and proposed plans to address these challenges.

Reviewer 3:
According to the reviewer, the presentation listed "Further improve cycling" and "Stabilize interfacial reaction" as proposed future work. The reviewer wanted to know what approaches will be taken to accomplish these tasks.

Reviewer 4:
The reviewer indicated that future work for improving the cycle life of 313 Wh/Kg for Li-S cells and 400 Wh/Kg for Li-NMC811 cells is well presented and effectively planned. It will be challenging to reach the goal of 500 Wh/kg for Li-NMC811 cells with long cycle life by the end of this project in 2020.

Reviewer 5:
The project team plans to increase the energy density by introducing new concepts, considering the balance between cycle life and thicker Li, and trying to limit cell shorting by charging at C/10. There is no plan given here.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer indicated that this project addresses the problem of capacity and energy stability with cycling. As such the project's outcome is important for the overall success of Battery500. The team's progress has shown stable cell performance at 350 Wh/kg, with indications of similar stability at the 400 Wh/kg level. These are important stepping stones for DOE's goal of 500 Wh/kg.

Reviewer 2:
This project will advance the development of high-energy rechargeable and low-cost Li-metal batteries for DOE EV applications.

Reviewer 3:
Ji Xiao's work directly addresses the DOE Energy Efficiency and Renewable Energy (EERE) Battery500 core objective.

Reviewer 4:
The reviewer found the project to be very relevant to DOE objectives.

Reviewer 5:
The project supports DOE's effort to increase the energy density of cells. However, the reviewer asserted that the team is not very forthcoming about what it is doing. It was if this were a presentation from a company that was protecting every bit of data because of intellectual property (IP). Is this a project meant to generate IP or provide guidance to other researchers toward making higher energy density systems?

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked that PNNL has the best equipment and resources for proposed milestones.

Reviewer 2:
The resources allocated to the project seem reasonable.

Reviewer 3:
Resources are sufficient.

Reviewer 4:
The team has sufficient resources to meet the Battery500 program goal.

Reviewer 5:
The PI for this project provided the total funding number. The reviewer can only assume that all $10 million was spent on the work presented. It should not be that hard to figure out how many folks actually contributed to creating the graphs of the data presented for this particular project or there may be a bigger problem in tracking the spending.

Presentation Number: bat370
Presentation Title: Advanced Diagnostics of Nickel-Rich, Layered-Oxide Secondary Particles
Principal Investigator: Mike Toney (Stanford University/SLAC)

Presenter

Mike Toney, Stanford University/SLAC

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 20% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

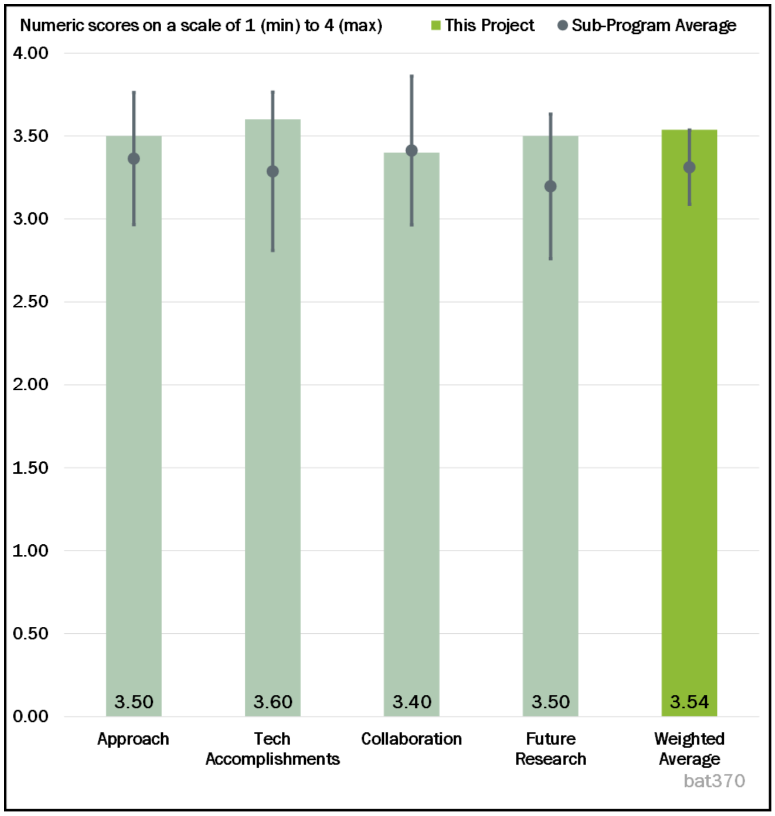

Figure 2-22 - Presentation Number: bat370 Presentation Title: Advanced Diagnostics of Nickel-Rich, Layered-Oxide Secondary Particles Principal Investigator: Mike Toney (Stanford University/SLAC)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The team uses in situ and ex situ synchrotron X-ray based spectroscopy and microcopy techniques to investigate the behavior of Li-rich cathode materials at different length scales. Using the structural, chemical, and mechanical information obtained from these studies, the project aims to provide understanding of materials-failure mechanisms. The reviewer asserted that this is an excellent approach that is well thought out and effective in addressing the barriers in cathode-materials development.

Reviewer 2:

In situ and ex situ X-ray probes were utilized to investigate the structure stability of Li-Mn-rich cathode materials. Concentrated effort was devoted to understanding the mechanism of O redox and the voltage fade during charging and discharging. The adoption of an element-sensitive technique to differentiate Mn, Co, and Ni will be a huge plus for this project.

Reviewer 3:

The projects bring together numerous approaches that can be used to evaluate O loss in Li-Mn-rich (LMR)-NMC and to understand the issues with this material. Both averaging tools and particle-level diagnostics were presented. The reviewer found the work to be very impressive.

Reviewer 4:

The objective of understanding the origin of activation and degradation of LMR-NMC is achieved.

Reviewer 5:
LMR-NMC materials have been well studied, especially using X-ray studies. The reviewer indicated that it is difficult to propose new studies that have not been done. Still, the quality of these measurements continues to improve.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer found the results to be impressive. The presentation showed how O loss occurs using a combination of tools. It was very comprehensive and detailed.

Reviewer 2:
The quality of these studies is excellent. The reviewer remarked that it is unfortunate that there is no synthesis collaboration that would allow more flexibility. The rich chemistry and microstructure of these LMR-NMC materials can have a huge impact on performance. It was hard for the reviewer to separate conclusions that are supported by previous work from the ones that are unique to this study.

Reviewer 3:
The team has made significant progress in terms of understanding O-redox active materials. The techniques used were appropriate, and the coupling of TM migration and O redox as well as the mechanism behind it were clearly explained.

Can the team illustrate the connections among O redox, TM migration, O vacancy, and O diffusion processes? Also, what triggers O redox and TM migration and which one comes first? The reviewer would like to see a more rounded picture of these processes and how they affect the performance of the cathode materials but understood that the project has now ended.

Reviewer 4:
The correlation between the TM migration with the O redox was observed. In addition, the periodic transition migration between the TM layer and Li layer was reported during the charging and discharging process. Phenomena- wise, this project successfully associates the slow kinetics of voltage fade to periodic migration of TM. As generally seen in this structure community, the potential impact of carbonated-based electrolyte at such high potential was not discussed at all.

Reviewer 5:
Technical accomplishments are clearly demonstrated in the presentation and summarized concisely on Slide 16.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The team made a good use of National Laboratory user facilities. According to the reviewer, the work was well coordinated.

Reviewer 2:
This team has a strong collaboration with other research teams and Battery Materials Research Program (BMR) projects.

Reviewer 3:
Excellent collaboration, though it was unclear to the reviewer what role the “industry” partner had other than providing the materials. Did the knowledge gained from the project help the industry?

Reviewer 4:
Some collaborations are listed. The work appears to be relatively independent.

Reviewer 5:
There are collaborations with the Advanced Light Source (ALS), but the reviewer did not see much more. Maybe that is okay, but the reviewer would like to have seen theoretical predictions complementing the experiments. There were theorists in the list of collaborations, but no results were presented.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
This project has ended.

Reviewer 2:
This is an end-of-project review. No future work was presented.

Reviewer 3:
The project has ended.

Reviewer 4:
There is no proposed future work, but the project has finished.

Reviewer 5:
It appeared to the reviewer that the future work seems logical.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Excellent fundamental studies were carried out in this project to improve existing cathode materials. This is highly relevant to DOE’s objectives in developing high-energy LIBs.

Reviewer 2:
In the past two decades, DOE has heavily invested in the material development of LMR cathode materials. This class of materials has a higher energy density than other counterparts. Further understanding the voltage-fade mechanism can shed light on the potential mitigation of such barriers and enable them for high-voltage and high- energy-density applications.

Reviewer 3:
The reviewer stated that fundamental knowledge gained through this project will be useful to help achieve the DOE objectives.

Reviewer 4:
If the results of this study would lead to a better LMR-NMC, then that would reduce the cost of batteries.

Reviewer 5:
The reviewer indicated that understanding voltage fade and oxygen loss is critical.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources were used to develop and utilize a correlative microscopy platform that included in situ and ex situ X-ray spectroscopy, diffraction, and microscopy to correlate local chemistry, structure, and microstructure evolution to battery performance and durability relevant to fast charging,

Reviewer 2:
The resources are sufficient, and the project was completed.

Reviewer 3:
The resources seemed sufficient to the reviewer to conduct the studies.

Reviewer 4:
There was good use of resources.

Reviewer 5:
The reviewer said that resources are sufficient.

Presentation Number: bat376
Presentation Title: Disordered Rocksalt Transition-Metal Oxides (TMOs): Recent Advances
Principal Investigator: Gerbrand Ceder (Lawrence Berkeley National Laboratory)

Presenter

Gerbrand Ceder, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

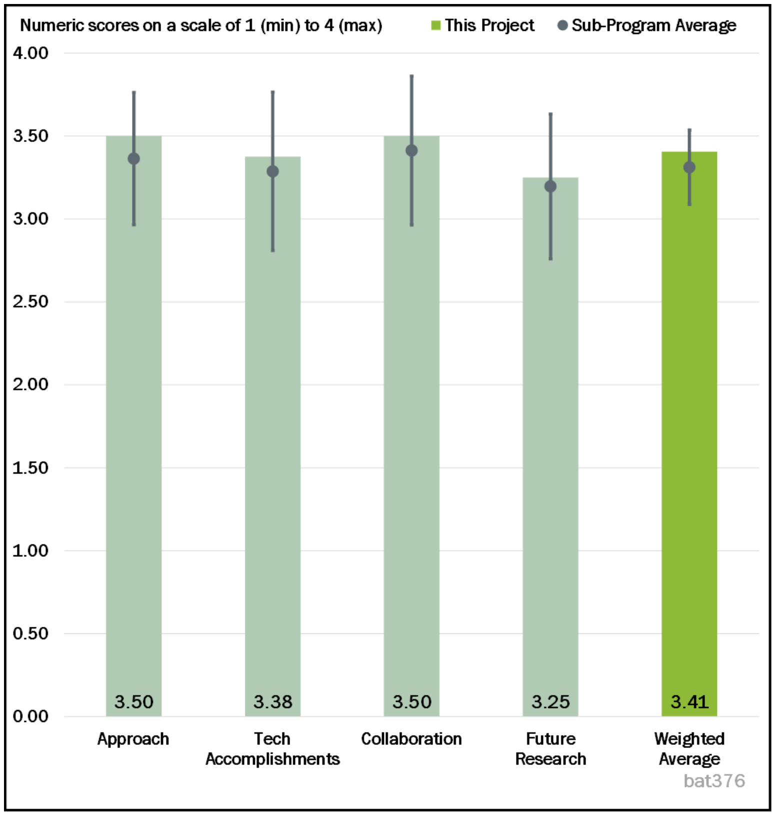

Figure 2-23 - Presentation Number: bat376 Presentation Title: Disordered Rocksalt Transition-Metal Oxides (TMOs): Recent Advances Principal Investigator: Gerbrand Ceder (Lawrence Berkeley National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The first presentation gave an overview of the cation-disordered rock salt (DRX) project and clearly described the motivation, barriers, and strategies with multiple teams. It indeed helped the reviewer to understand the big picture of the overall DRX project. The second presentation focused on surface studies and high-voltage potential, especially on Li-Mn-Nb-O-F (LMNOF). The project has addressed the technical barriers adequately and demonstrated the effectiveness of problem-solving efforts.

Reviewer 2:

The approach focused on three DRX baseline powders (none of them with Co content) coupled with a variety of spectroscopic techniques, and the modeling studies are impressive. The project is good and feasible.

Reviewer 3:

DRX is a promising new class of Co-free Li-ion battery cathodes.

Reviewer 4:

DRX materials provide attractive alternatives to NMC-type cathodes. The reviewer remarked that it is good that whole team is working on the selected three materials. Co replacement by Nb or Ti may be even more problematic in terms of the material sustainability. Another concern is the high content of reactive F, which may be significantly problematic when batteries catch fire and result in the release of hydrofluoric acid (HF).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The overall DRX project has reached several impressive findings and accomplishments. The second presentation first expressed the key observation on the Li-Mn-Ti-O-F (LMTOF) and LMNOF. The team utilized several techniques and approaches to investigate the cathode itself and evolution with electrolyte upon cycling for LMNOF. In the study focused on surface analysis, the reviewer observed that it would be interesting to correlate with bulk imaging for structural analysis to understand the dissolution and structure change.

Reviewer 2:
According to the reviewer, the amount of technical information the team managed to collect on these novel DRX compounds was impressive. The modeling and calculations the team presented, such as the one used as guidance for the F-substitution experiments, were impressive. It could be of great interest if the team can put together a simple model to explain the reason behind the lower surface energy found for the 001 and 110 facets, for example.

Reviewer 3:
The F solubility issue has been examined. The voltage-fade issue is a link to electrolytes. The reviewer noted that the short-range order was studied in depth using a variety of complementary techniques.

The composition is widely varied and studied; it would be useful to develop some unifying quantitative mechanism that can explain the data.

There is an interesting transition observed between spinel and rock salt structures and the resulting stabilization effect. The reviewer said that the in-depth surface study was well done.

Reviewer 4:
There were good insights on surface characteristics of LMTOF materials as well as interesting insights on the mitigation of voltage and capacity fade via pre-treatment.

The overall performance still seemed underwhelming to the reviewer; perhaps more time is needed to fully understand this interesting new material and its practical usefulness.

Extending the disorder concept to spinels is innovative.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The teams strongly collaborate with each other; in particular, the reviewer remarked that it is nice to see the theoretical group strongly interacting with the experimentalists and complementing each other.

Reviewer 2:
It is an excellent team and collaboration.

Reviewer 3:
In the presentation, the reviewer clearly saw the overall DRX project, which indicated how the teams contributed their efforts to the novel DRX materials. To develop and understand the novel materials, the challenges are inevitable. It requires good collaboration and coordination between teams. As the work includes a great collaborative effort from several areas of experts, the reviewer suggested that efficient communications and learnings across teams could speed up the development process.

Reviewer 4:
The reviewer found collaboration to be good.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed plan is generally well thought out and demonstrates the clear knowledge of the key challenges from synthesis improvement, material design, and investigating the origin of electrochemical properties. As the project focus is toward F optimization and understanding, the reviewer said that it could be helpful to design the strategic approach to study and compare regular DRX and fluorinated DRX materials.

Reviewer 2:
The evaluation of the F-solubility limit seems very important as it may hint at potential improvements for these DRX powders. The reviewer found it very interesting to see that the source of F released from these DRX powders is coming from lithium hexafluorophosphate ($LiPF_6$) present in the electrolyte. The studies focused on the surface versus bulk effects of the electrochemical performance degradation for these powders, which seem very important, and the team is already fully involved in that area. The synthesis of these DRX materials could become very important in the future, in particular when trying to scale up the production process for these DRX compounds.

Reviewer 3:
This is an extension of the current work.

Reviewer 4:
The future work is adequate; perhaps it can be more ambitious in terms of actual performance improvements.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The novel DRX materials provide the potential for the alternate cathode material. It is well aligned with DOE-VTO objectives.

Reviewer 2:
This project is very relevant for the DOE objectives. As the team members have shown, the three DRX powders presented in this study, for example, are absolutely Co free.

Reviewer 3:
This project is relevant to DOE objectives.

Reviewer 4:
Work is relevant to the program, but it was not clear to the reviewer if the proposed cathode material is environmentally sustainable.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The DRX project gathers sufficient resources from several talented teams and National Laboratories. The reviewer stated that the team has adequate credentials, experience, and resources to execute the project.

Reviewer 2:
The team has a good access to the needed resources.

Reviewer 3:
Resources are sufficient.

Reviewer 4:
The project may need additional support if DOE decides to scale up the production process for these new types of materials.

Presentation Number: bat388
Presentation Title: Silicon Deep Dive: Update and Overview
Principal Investigator: Jack Vaughey (Argonne National Laboratory)

Presenter

Jack Vaughey, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

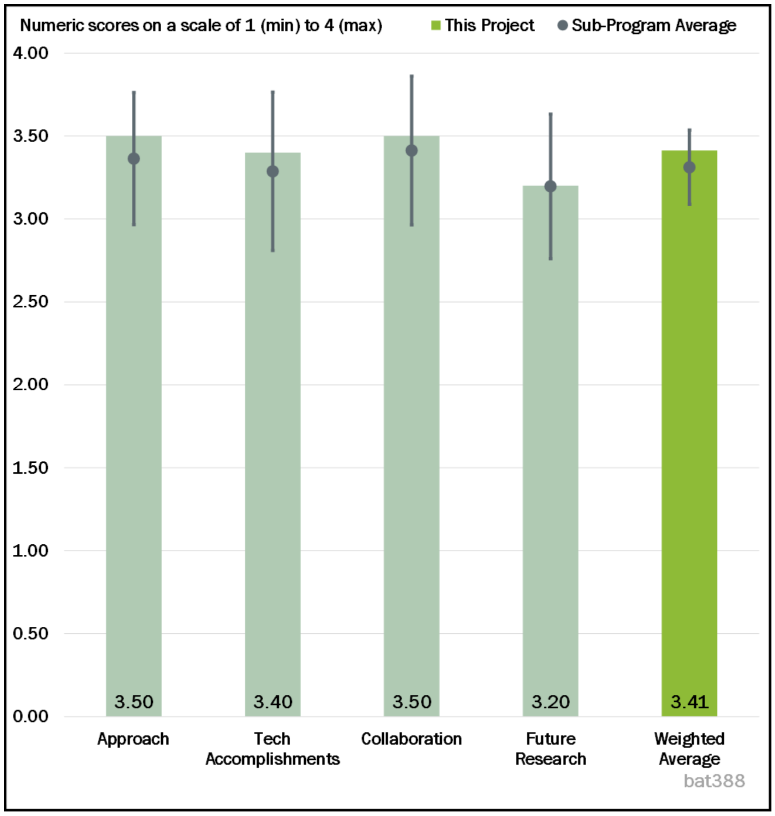

Figure 2-24 - Presentation Number: bat388 Presentation Title: Silicon Deep Dive: Update and Overview Principal Investigator: Jack Vaughey (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The work on cell design and electrodes is really critical and under-represented in the industry. The reviewer was very glad to see this work included in the project. The work on FEC is also practically important since it is so heavily used with Si. The reviewer thought that this presentation was the most relevant to commercial systems.

Reviewer 2:

The project is well organized, well designed, and highly focused. It was very evident to the reviewer that a lot of careful thoughts went into planning this project.

Reviewer 3:

The Silicon Deep Dive is focused on addressing calendar life and cycle-life issues with Si-anode technology. The team is taking a practical approach via materials stability, cell and electrode design, and failure analysis. Various responsible parties on the sub-thrusts are easily identified and project areas are delineated. Project categories are appropriate for solving Si issues.

Reviewer 4:

The overview to the Silicon Deep dive program did a good job of addressing the important technical barriers and does a good job coordinating the large number of researchers working on the project. The goals of the project are clear, and the design of the work groups and work packages are good. The project has feasible goals that will likely provide benefit to the U.S. automotive industry by laying the groundwork to improve the energy density of anodes for LIBs.

Reviewer 5:
It was not clear to the reviewer what new approaches are being taken to make Si viable: C coatings have been tried over many years. Please explain how these experiments can lead to improved batteries.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
This project has addressed four critical topics related to the development of Si anodes for LIBs. First, what is the quality and surface chemistry of the Si materials along with the design of the cells? These are important issues, and the team has addressed the problems in a systematic and effective manner.

The second area is slurries and laminate design. This issue is a very important challenge for Si electrodes and is often overlooked in research settings. The team has approached the problems in a very systematic manner and has developed novel methods to investigate changes to both slurry design and laminate structure and the effect on performance.

The third area is surface functionalization. It was clear to the reviewer that one of the primary problems associated with Si-anode materials is the surface chemistry of the Si particles. The team has designed some interesting and novel methods to modify the surface of the Si particles to improve the performance.

The surface functionalization is related to the fourth area, which is SEI formation and stability. The SEI on Si anodes is very complicated and important for the overall function of Si anodes. The team has utilized novel methods to investigate the thermal stability of the SEI with different electrolytes. This study has provided important fundamental information, which will greatly benefit the development of Si anodes.

Reviewer 2:
This project has a lot of practical progress. The reviewer appreciated that the team addressed a reviewer comment from last year that the project was too exploratory. The reviewer thought that there is a much better balance now, and technical accomplishments are very relevant.

Reviewer 3:
The project has made significant contribution toward fundamental understanding of Si-anode properties using a variety of state-of-the-art analytical techniques. This has been the salient feature of these investigations, and the reviewer gave kudos to the teams for doing an excellent job in achieving this objective.

The reviewer was kind of hoping that this high-powered talented team with significant resources and time will be coming up with a solution for the Si anode that will be ready for use in a long-life cell. However, based on the current data, it was not clear to the reviewer that the teams were able to achieve that goal.

Reviewer 4:
The presenter described significant technical accomplishments that occurred over the previous year. For example, the development of the porous Si material with C coatings appeared to the reviewer to be a significant development and should be investigated further as it seems to be a practical approach to improving Si performance. Additionally, the discussion of full-cell design and related electrode expansion was refreshing to the reviewer and demonstrated an understanding of some industrially relevant metrics for commercialization. Technical Accomplishments are practical and may be applied more broadly to other systems as well.

Combining some of the most promising approaches together to confirm that they are additive rather than "mutually exclusive" would be re-assuring regarding the validity of the approach (i.e., porous Si-C material, with improved negative-positive (N/P) ratio studies, and Mg-salt addition). Parenthetically, the reviewer also asked does each part lead to incrementally better performance and would the SEI still show dissolution with the Mg salt and porous Si-C material?

Reviewer 5:
The reviewer provided the following comments:

- The Si results look good, but no CE numbers are provided.
- Si-tin (Sn) results are available for only 20 cycles.
- Slide 9 shows "Less Si is cycled as the negative cycling window changes; this would decrease the electrode volume expansion and reduce the rate of capacity fade as the aging progresses." This is well known; limiting Si utilization is a standard approach for Si in electrodes.
- The reviewer did not see an overarching, overall strategy that will lead to a Si-based anode or full cell.
- Increasing the N/P ratio adds weight. Why not just limit voltage range, which is normally done, to increase lifetime?
- Binder interactions are a very important area to study.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This is an overview of a large team project. The team clearly interacts regularly and utilizes the resources of different National Laboratories effectively. The projects leaders do a good job of coordination of the many different projects. Since the performance of Si anodes is dependent upon many different factors, a large team approach with many different researchers studying the same materials is very important for the development of a consistent understanding of these complicated materials.

Reviewer 2:
The reviewer noted that this is a well-coordinated team project that really leveraged the excellence of each National Laboratory.

Reviewer 3:
Specific collaborations are called out. The reviewer wanted to know how this collaboration connects to that of Burrell.

Reviewer 4:
The presenter highlighted collaboration and coordination between project teams and mentioned at the outset how the individual pieces fit together. The reviewer found this to be very well organized and well-presented regarding collaboration and coordination.

Reviewer 5:
There seems to be good collaboration across a very large team. The reviewer would like to have seen more cross- team conclusions drawn from pooled results.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The presenter highlighted appropriate remaining challenges and barriers as well as future work to address those issues. Some future work was concrete (i.e., better slurry processing routes, identifying the role of additives in aging and slurry stability, and Si-specific Battery Performance and Cost models), and directions were well thought through. Efforts to improve reproducibility and evaluation were also described (develop new scale-up processes), which are very high priority to ensure that results can be generally applied and are not limited to small-scale individual investigations.

Reviewer 2:
The proposed future research areas are the most important topics for further development of Si anodes. The effect of SEI structure, stability, and dissolution will lead to the development of superior surface films and improved performance. Continued evaluation of the slurries will also lead to important practical advances. Finally, the development of consistent materials for investigations will greatly assist uniformity of the investigation across the entire team.

Reviewer 3:
The reviewer's reservation was whether the proposed work will lead to a commercially viable solution and be competitive with state-of-the-art Si technologies.

Reviewer 4:
Future work focuses on functionalization/modification of the Si surface. The reviewer asked about the certainty of knowing what functionalities will ultimately succeed as the reviewer thought that it might be a little too early to talk about scale up.

Reviewer 5:
After decades of work on graphite SEI composition and structure, the reviewer was not aware of how these studies have led to any battery improvements. Instead, improvements have come from empirical approaches to add various additives. These additives were mostly discovered without the benefit of understanding how they work. Therefore, and by analogy, the reviewer was not convinced that an improved understanding of Si SEI will be a useful path forward.

There is no discussion of calendar life.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is very relevant since it is focused more on the applied research portion of the Si-anode development. The reviewer commented that Si anodes are a key technology to decreasing battery costs, increasing EV adoption, improving our energy independence, and becoming a world leader in battery technology.

Reviewer 2:
This project supports the DOE objectives of developing lower cost, higher energy density LIBs for electric vehicles. The development of improved Si or Si-C composite anodes is one of the few viable methods to increase the energy density of the anode for LIBs. This team is addressing the important problems in an appropriate manner.

Reviewer 3:
The reviewer noted that Si anodes are required to achieve the DOE energy-density roadmap for automotive application. This project seeks to understand and address the challenges of implementing Si in automotive cells with long cycle life and calendar life.

Reviewer 4:
This project is highly relevant to DOE's overall objective.

Reviewer 5:
Is $125/kWh good enough to be worthwhile studying?

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources seemed appropriate to the reviewer and sufficient to achieve the program milestones and have coordination and collaboration between the partners.

Reviewer 2:
The reviewer believed the resources and the time provided to this project were sufficient and significant.

Reviewer 3:
Resources are sufficient.

Reviewer 4:
The resources are sufficient.

Reviewer 5:
The reviewer thought that resources are sufficient—it is a very large team.

Presentation Number: bat392
Presentation Title: Enabling Rapid Charging in Lithium-Ion Batteries via Integrated Acoustofluidics
Principal Investigator: James Friend (University of California at San Diego)

Presenter

James Friend, University of California at San Diego

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

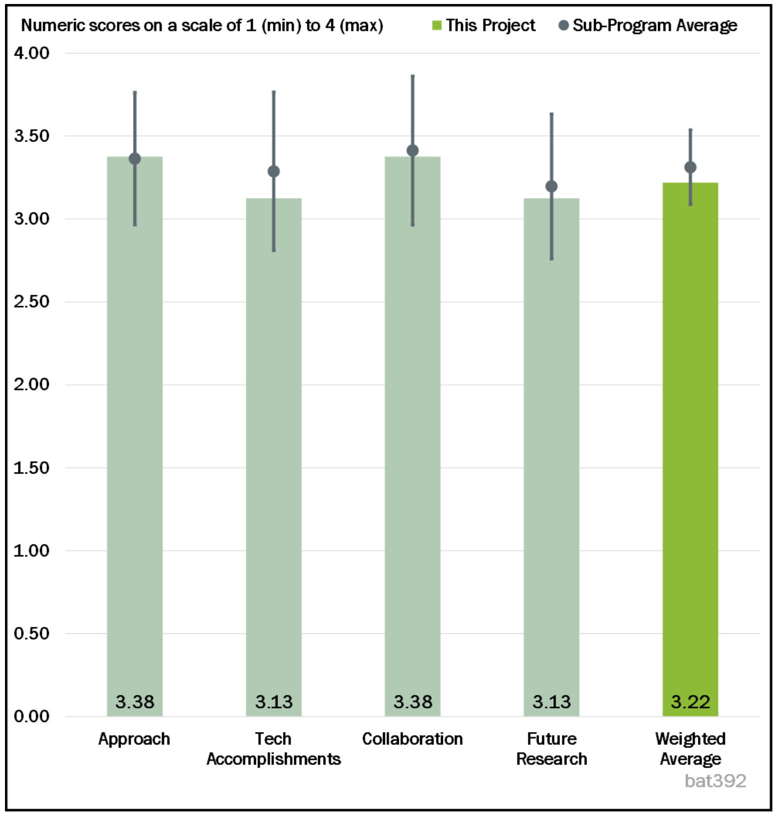

Figure 2-25 - Presentation Number: bat392 Presentation Title: Enabling Rapid Charging in Lithium-Ion Batteries via Integrated Acoustofluidics Principal Investigator: James Friend (University of California at San Diego)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The research showed clear improvement in capacity attained during fast charge. According to the reviewer, it will be more feasible if the device can be utilized external to the cell as proposed for future work. It may also be of interest to look at electrolyte systems that have favorable attributes, such as non-flammability or high-voltage tolerance yet are too viscous for application. This might be another application of this technology. Making the device smaller will make it more feasible.

Reviewer 2:

The approach, to start with, was to improve the fast-charging capability of the baseline Li-ion cells by choosing appropriate electrode materials and electrolyte components and understanding the effects of temperature. In parallel, the project has focused on the design and optimization of the surface acoustic wave (SAW) device tailored to the battery, the material characterization in the cells cycled with the integrated SAW, and the development of a model for the acoustically driven fluid flow. The approach here is feasible conceptually to enhance Li-ion mobility for preventing dendritic Li deposition at high charge rates.

One serious limitation of this technology is its invasive nature: i.e., the device is in intimate contact with the electrolyte. Even though it appears there is little effect on the cell performance with the integrated SAW within the cell, its long-term effects will be questionable. The reviewer commented that it would have been better if such a device can be instrumented outside the cell, which will eliminate this problem and also allow the commercial cells to be used with the device.

The task is well oriented to improve fast-charge capability of Li-ion cells, as required for EV batteries. The project is well integrated with other VTO projects.

Reviewer 3:
The technology offers the potential of improving the fast-charging capabilities of a single cell or a full system. It was not clear to the reviewer, however, how it can be easily implemented into or onto a cell and/or module for a vehicle application. Would the system need to be placed on every cell in a battery pack? If it were placed on a module or pack, is there a need for the sonic wave to be consistent across each cell? If so, how would that consistency be maintained across each cell and not introduce any life issues?

Reviewer 4:
The technical approach addresses the battery fast charging by using SAW on cells developed in-house.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The SAW LIB showed an almost two-fold improvement in energy density under fast-charge (15 min.) conditions, indicating good progress. The lifetime of the cell is improved. The reviewer suggested that some thought should be given to application in a multi-cell battery.

Reviewer 2:
Overall, the progress achieved here is meaningful and relevant to DOE goals. Reasonably good progress has been made in demonstrating the efficacy of the SAW device in promoting Li-ion diffusivity and thus the performance during cycling at high charge rates. The SAW device has been successfully miniaturized for incorporation into the cells. Also, characterization of the cycled batteries indicate that the electrode degradation is reduced with SAW. The results are interesting and encouraging. However, the reviewer had a few questions and a comment, as listed below:

- Why is the specific energy so low for the baseline cell (100 Wh/kg)? The challenge is to have high charge capability in a high energy cell with dense electrodes. Are the specific energies mentioned here normalized to low rate charges and discharge (e.g., C5-C/10)?
- Was the SAW device integrated in a jellyroll cell (20700)? Data for the pouch cell are only shown here.
- What causes the cathode to degrade in regions away from the SAW device?
- There is no change in the anode from neutron diffraction. Does it mean the differences caused by the SAW device are only on the surface of the anode, not the bulk? Does it imply that the SAW does not prevent Li plating but only prevents dendrites?
- Even though the cycle life is good with the SAW integrated within the cell, the total duration for this test is less than a month. The long-term effects of the SAW being in contact with electrolyte are therefore still unknown.
- How is the SAW sized for a given cell in relation to the size of the cell, amount of electrolyte, etc.?

Reviewer 3:
The technical approach is sound, and the progress is aligned with the plan.

Reviewer 4:
The project demonstrates that the technology improves the fast-charge capabilities of a single cell. Ideally, the project needs to confirm the overall effectiveness of the technology in a high-voltage vehicle battery with a cell format 35 Ah or greater. Also, the application would need to be at either the module or pack level rather than at the cell level.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There are good, on-going collaborations with the University of California at San Diego's Qualcomm Institute for the design and testing of SAW circuit, with ORNL for neutron characterization on cycled Ah pouch cells, and LiFung for the fabrication of large format pouch LIB cells. It was not clear to the reviewer where the cylindrical (jelly) roll cells 20700 were made, however.

Reviewer 2:
The reviewer noted that the collaborations seem to work okay in the context of this project. The partners worked on the areas of their expertise. The feedback loop between the collaborators was not that evident to the reviewer, but the positive results suggest that it worked at some level.

Reviewer 3:
The project appeared to the reviewer to be involving the right teams to make the technology work. More involvement with a final end user (i.e., vehicle original equipment manufacturer [OEM]) would help.

Reviewer 4:
The contractor has put together a strong team with extensive experience in attacking battery fast-charging technical barriers.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer remarked that significant challenges still remain in implementing this technique in LIBs to improve to fast-charge capability. These are related to placing the μ-particle image velocimetry on a transparent battery to improve the mathematical model used for design; placing the SAW in a large LIB; and placing the SAW outside the cell so that it may be retrofitted in commercial LIBs. Finally, being chemistry-agnostic, the SAW-driven, acoustic-streaming approach may be extended to Li-metal batteries, including Li-S, to prevent dendritic Li deposition during charging. Future studies in this project are planned effectively and logically.

Reviewer 2:
The reviewer indicated that the project needs to clearly show how the technology cost will be controlled and how the processing and manufacturing will be done to incorporate the technology in order to maximize its effectiveness. These two concerns seem to be part of any future development work.

Reviewer 3:
Demonstration across platforms would be of interest. Thick loadings might also be of interest. Using this tool to enable electrolytes that might be too viscous under normal operating conditions might be of interest. Application in a multi-cell pack needs to be thought out and done.

Reviewer 4:
The presentation did not include the impact of acoustic waves on electrode over-potential. The reviewer suggested that the project add electrochemical study on the impact of acoustic waves on cell overvoltage if it has not been done. In addition, the reviewer suggested adding a study on comparing coulombic efficiencies with and without acoustic waves during fast charging.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The overall objective is to increase the energy density of Li-ion cells to more than 180 Wh/kg during fast charge (6C), and the premise is that improved Li-ion diffusion in the electrolyte from acoustic streaming will allow rapid charging without the formation of dendrites. Specifically, this project has developed a scheme to integrate the SAW device in a Li-ion cell to enhance Li mobility between the electrodes and mitigate the interfacial degradation at the anode during fast charge. Additionally, a mathematical model is being developed for Li diffusion in the presence of acoustically driven flow and to correlate the predictions with the experimental data.

According to the reviewer, the project duly addresses the barrier of low specific energy of Li-ion cells during cycling involving fast charge. The project is well designed and well planned to enhance rapid-recharge capability of LIBs, which is one of the requirements for EVs and is thus consistent with the goals of DOE-VTO program.

Reviewer 2:
The reviewer found a clear need to improve the fast-charge capabilities of current, high-voltage electrified vehicle systems to make them more acceptable. The development and implementation of this technology offers a chemistry-agnostic solution that will help move the needle in that acceptance direction.

Reviewer 3:
The reviewer stated that it is relevant to lowering the tradeoff in energy density and lifetime that occurs in state-of-the-art (SOA) cells under fast-charge conditions. Fast charging may increase driver acceptance of EVs.

Reviewer 4:
The project supports the goals for battery charging-time reduction.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The funding seemed sufficient to the reviewer, considering that commercial off-the-shelf (COTS) battery materials are used for cell construction and the device is also build from COTS components.

Reviewer 2:
The resources are appropriate for the scope of the project.

Reviewer 3:
The resources appeared to be sufficient to the reviewer for the proposed efforts. But it may save time for the team to have a partner (such as a National Laboratory) in building cells with specific energy density meeting the requirement for the experiment.

Reviewer 4:
The resources are sufficient to develop and demonstrate the technology. Involvement of end users should be viewed as the next step.

Presentation Number: bat393
Presentation Title: Development of an Extreme Fast-Charging Battery
Principal Investigator: Chao Wang-Yang (Penn State University)

Presenter

Chao-Yang Wang, Penn State University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

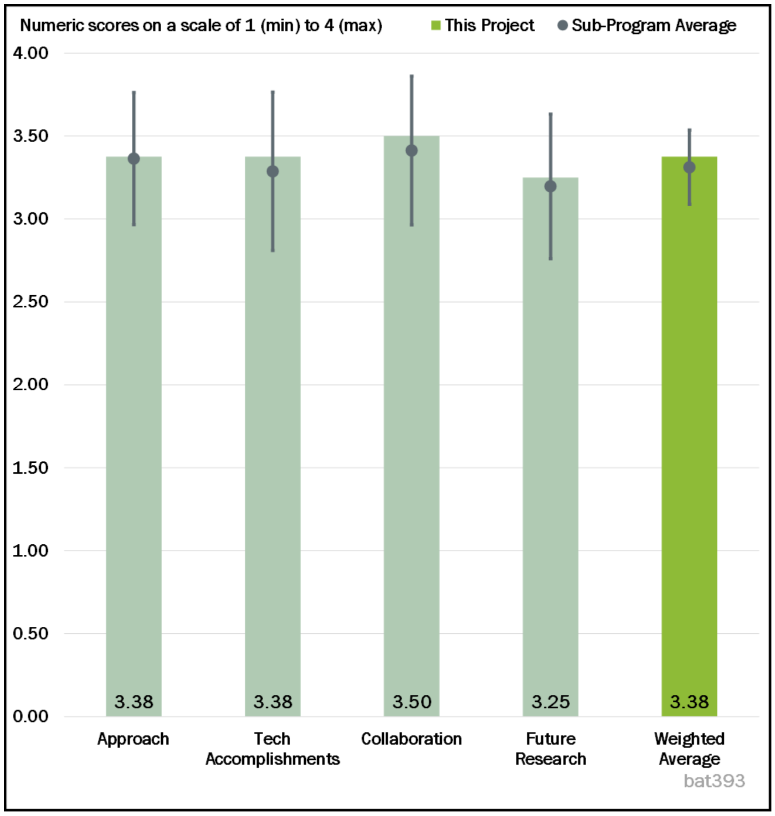

Figure 2-26 - Presentation Number: bat393 Presentation Title: Development of an Extreme Fast-Charging Battery Principal Investigator: Chao Wang-Yang (Penn State University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project seemed well designed to the reviewer and fairly feasible. Feasibility may depend on the development of new electrolytes and their applicability for thick electrodes. Going to very high temperatures to overcome challenges of thick electrodes likely will result in a tradeoff in cell lifetime.

Reviewer 2:

According to the reviewer, the approach is based on an asymmetric temperature modulation—charging at a high temperature (greater than 60ºC) to prevent Li plating and discharging at ambient temperatures. Li-intercalation kinetics at the anode seem to be accelerated at warm temperatures (60ºC), and the brief stay at the high temperature during fast charge (i.e., for ~10-min./cycle) does not seem to cause performance degradation. Self-heating is provided by a Ni foil inserted into the cell and connected to the third terminal, which is heated by power sources used for charging the cell.

One limitation of this technology is its invasive nature: i.e., the device is integrated into the cell. It would be better if such rapid heating can be achieved outside the cell, which will allow commercial cells to be used instead of focusing on cell optimization in this project with dense electrodes to provide high specific energy in combination with fast charging. The task is well oriented to improve fast-charge capability of Li-ion cells as required for EV batteries. The project is well integrated with other VTO projects.

Reviewer 3:

The technical approach addressed some key technical barriers related to battery fast charging in terms of charging methodology and cell design.

Reviewer 4:
The reviewer remarked that the approach for the test was well designed and feasible for the chosen test sample type. The test showed that heating up a large cell (35 Ah?) prior to a fast charge would improve the ability of the cell to accept a fast charge, without it negatively impacting cell life. This work however did not address concerns for doing this at a module or pack level or with the cell clamped. The addition of these test conditions is needed for technology evaluation.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Progress toward the goal of improving fast-charge capability at the cell level was shown to be excellent. The overall impact on life for a high number of fast-charge events was better than expected. The additional cost of heating an entire pack and the time needed was not clear to the reviewer, however, and the effect of both could present issues.

Reviewer 2:
The demonstration of an improved electrolyte was encouraging to the reviewer. Questions might arise as to what cost that would add to the cell, which might hinder its acceptance. The performance has been verified independently, which is also encouraging. The tradeoff in cycle life is a large challenge to overcome.

Reviewer 3:
Good progress has been made in demonstrating the beneficial effect of preheating the cell with an internal device on the anode kinetics, improving the fast-charge capability of Li-ion cells without Li plating, and demonstrating good capacity retention during cycling, despite the brief exposure to warm temperatures. It was demonstrated that, with rapid preheating of less than 1 min. prior to charging, the cell gets to the optimum temperature to allow fast charging without plating. Gen-2 cells fabricated with denser electrodes showed improved specific energy and good cycling behavior at normal rates, but poor rate capability and poor performance with fast-charge cycling even after cell heating and need further development.

Modifications in the electrolyte have resulted in slightly improved performance under fast-charge cycling conditions, but the fade is still higher than desired. There are plans to modify the anode binder, but they have not been implemented yet.

The results are promising. It appears that this technology is more amenable to pouch cells. Can this be implemented in cylindrical cells? It would be more beneficial to collaborate with a commercial battery manufacturer to integrate this device in commercial cells so that this project can focus on improving fast-charge capability rather than specific energy. Overall, the progress achieved here is meaningful and relevant to DOE goals.

Reviewer 4:
The technical progress has been achieved as planned.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration to find a new electrolyte is an outstanding demonstration of working across organizations.

Reviewer 2:
The collaboration across the team members appeared excellent to the reviewer.

Reviewer 3:
There are good on-going collaborations with the faculty member from the same university and with the ANL researchers for developing new high-temperature electrolytes and also in evaluating the pouch cells. It may not

be too early to partner or collaborate with a commercial cell manufacturer for validating this approach in commercial high-energy cells.

Reviewer 4:
The appropriate teams were involved in this project to effectively demonstrate the intended technology for the identified sample type. The need for an appropriate vehicle module or vehicle battery for testing could require the addition of a vehicle manufacturer or a battery supplier to the team.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Significant challenges still remain relative to the Gen-2 cells with thick electrodes, which show serious Li plating, even with the modified electrolyte. Further improvements are desired in the high-temperature electrolyte. Future studies will focus on electrolytes with high diffusivity and transference number, electrolyte additives, or even cathode coatings for improved resilience at high temperatures. Future studies are planned effectively and are consistent with the objectives, according to the reviewer.

Reviewer 2:
The reviewer noted that figures on Slide 7 proved the validation of battery fast charging at 60˚C. For better comparison, the reviewer suggested studying conditions of 1C charge at 60˚C and 1C discharge at 27˚C to compare the impact of charging rate to battery life at high temperature.

On Slide 7, the cycle-life data with the same marked testing condition have different decay rates. Is there any typo in these testing conditions? Though it is not the major focus of this project, the reviewer hoped to see the PI talk with battery and charger industries for potential technology transitioning.

Reviewer 3:
The reviewer stated that battery pack and module testing for this technology approach is needed and appears to be identified as part of future plans.

Reviewer 4:
The proposed future research is very general and appropriate for increasing fast-charge capabilities. The reviewer suggested that perhaps something more specific to the method of this project should be included in future work.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The overall objective is to enable rapid recharging of Li-ion batteries to a minimum of 80% SOC within 10 min. The strategy for achieving the fast-charge capability is based on heating the cell to 60^{o}C to improve anode kinetics. Related performance targets are to achieve high specific energy greater than or equal to 225 Wh/kg at the cell level and good cycle life greater than 1,000 cycles at 20% capacity fade in the cells accommodated with the self-heating scheme. Fast charging, which is being addressed here, is one of desired performance characteristics for EV batteries and will enable a widespread use of EV batteries, especially with higher specific energy and lower cost targeted here. The reviewer commented that the project is well designed and well planned and is consistent with the goals of the DOE-VTO program.

Reviewer 2:
The goal of the project is to develop fast charging of batteries using temperature modulation. According to the reviewer, this will lead to improved charging performance in line with DOE objectives.

Reviewer 3:
The project supports the goals for battery-charging-time reduction while the cell keeps reasonable high-specific energy density.

Reviewer 4:
Fast-charge capability is needed for the acceptance of the electric vehicle as a viable alternative to internal combustion (IC) powered vehicles.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer indicated that funding seems to be about right considering the need for cell builds and the labor and equipment needed for experimental work.

Reviewer 2:
The resources are appropriate for the scope of the project.

Reviewer 3:
The resources appear to be sufficient for the proposed efforts.

Reviewer 4:
The resources are appropriate for the stated milestones.

Presentation Number: bat394
Presentation Title: Highly Ordered Hierarchical Anodes for Extreme Fast-Charging Batteries
Principal Investigator: Neil Dasgupta (University of Michigan)

Presenter

Neil Dasgupta, University of Michigan

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

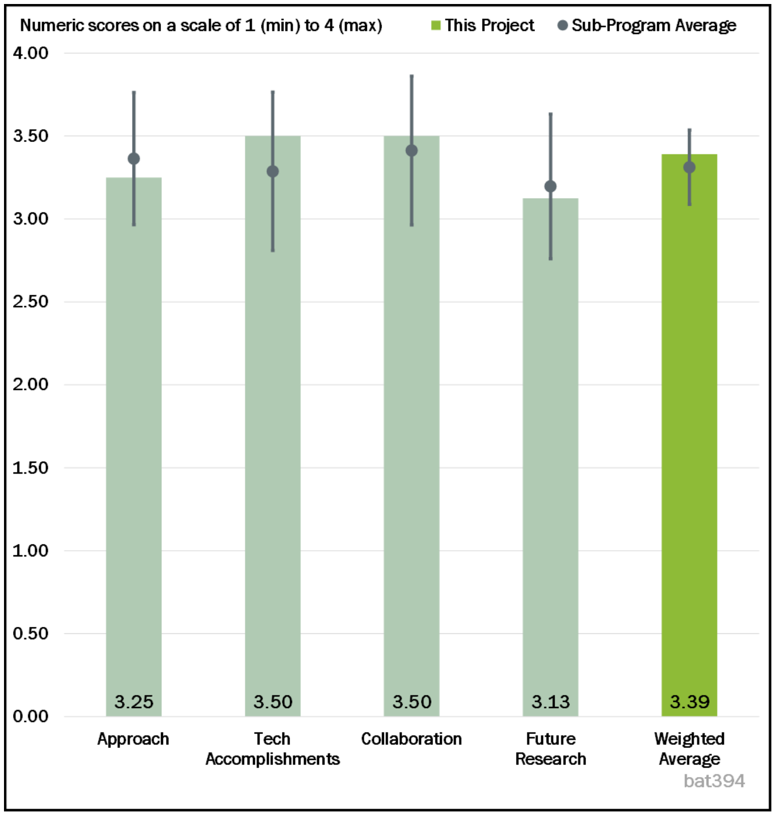

Figure 2-27 - Presentation Number: bat394 Presentation Title: Highly Ordered Hierarchical Anodes for Extreme Fast-Charging Batteries Principal Investigator: Neil Dasgupta (University of Michigan)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the work shows good proof of concept for the use of laser patterning of graphite electrodes to improve fast-charge capability of thick electrodes. The fast-charge objectives were met. The approach allows the existing infrastructure to remain with the addition of one processing step at the end.

Reviewer 2:

The project required a new method to increase fast-charge capability without increasing the possibility of Li plating, which negatively impacts life and performance. The work involved using lasers to create ordered holes in the anode layer. The technical barriers to do this work were addressed and the design was proven to be feasible.

Reviewer 3:

The approach is based on creating highly ordered laser-patterned electrodes to improve the permeability of Li ions deep inside the electrodes, which will reduce the anode polarization and improve its utilization during fast charge. To augment the experiential design of the anode, modeling studies were carried out to predict concentration gradients as a function of pore diameter and spacing. To directly examine the plating behavior, operando video microscopy has been used and confocal Raman imaging is being planned later. In addition to the modifying the bulk properties (porosities) of the anode, thin coatings of ionic conductor were applied on graphite anodes, though this is unconnected with the project objective of creating channels in the anode for enhanced Li^+ permeability.

Increasing the porosity (with low tortuosity as here) would no doubt benefit the high rate performance, but the reviewed said that there are a few adverse effects. More electrolyte will be needed to fill the pores, which will increase the cost and reduce the specific energy and energy density. Additionally, the increased surface area (which benefits here due to reduced current density at the anode) may result in higher irreversible capacity for SEI formation. Implementation of this in commercial cell electrode/cell fabrication processes will still be a challenge.

The task is well oriented to improve fast-charge capability of Li-ion cells, as required for EV batteries. The project is well integrated with other VTO projects.

Reviewer 4:
The technical approach addressed battery-cell design capable of fast charging with minimum cost increase. While the technical approach is impressive, the reviewer remarked that it is not unique. A similar approach was published by Habedank et al in *J. Electrochem. Soc*. 166 (16) A3940-A3949 (2019).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer found the progress toward meeting the goals of the program to be excellent. The measured Li-plating issue was significantly reduced versus not using the method implemented, with little or no performance degradation.

Reviewer 2:
The reviewer noted that there are several publications indicating good progress in the scientific understanding and documentation of the results. Practically, the goals of the extreme fast-charge (XFC) program are met by this approach.

Reviewer 3:
Good progress has been made in demonstrating the benefits of laser-patterned channels in improving the anode utilization during fast charge, without the problem of Li plating from post-mortem analysis and in demonstrating the scalability of this process in 2 Ah cells. The reduced concertation polarization at the anode was verified by parameterized computational model. Finally, high-precision coulometry differential capacity (dV/dQ) analysis was used to track Li plating in the cells with control and modified anodes. The results are promising, but led the reviewer to make the following points:

- Even though there is an improvement in performance with this approach during XFC cycling, the specific energy and capacity retention of the test articles (2 Ah cells) is not impressive.
- Three-electrode cells with this highly ordered laser-patterned electrode (HOLE)-graphite anode will provide better understanding of the polarizations at the individual electrodes, if any such modifications are needed at the cathode also.
- It would be more beneficial to collaborate with a commercial battery manufacturer to validate this approach in commercial cells, instead of developing high-energy cells in a university set-up.

Overall, the progress achieved here is meaningful and relevant to DOE goals.

Reviewer 4:
The technical progress was made on plan.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaborations demonstrated with UM, several DOE National Laboratories, and international partners enabled access to unique capabilities, according to the reviewer.

Reviewer 2:
The reviewer found the team work to be well coordinated.

Reviewer 3:
The appropriate teams needed for the project were in place to meet the goals of the project. The collaboration between the teams was appropriate with each team making use of its specific strength.

Reviewer 4:
There are good, on-going collaborations with the DOE National Laboratories—SNL for high-precision coulometry and rapid EIS capabilities, ANL for providing electrodes for hole modification and later testing them, SLAC National Accelerator Lab for operando synchrotron XRD of HOLE electrodes during XFC—and ETH Zürich for X-ray tomography of HOLE electrodes.

The reviewer suggested that it may be useful to partner or collaborate with a commercial cell manufacturer for validating this approach in commercial high-energy cells, instead of attempting to optimize pouch-cell fabrication for achieving high specific energy.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Scaling up to larger capacity cells is a good approach. Demonstration in a multi-cell pack would be of interest to the reviewer. Demonstration of the precision of the capacity achieved is needed for mass-scale manufacturing acceptance.

Reviewer 2:
Significant barriers remain relative to achieving industry-relevant, high-throughput processing for HOLE anode fabrication and for achieving high specific energy in pouch cells (250 Wh/hg), both of which the reviewer said pose considerable challenges. Future plans also include continued use of high-precision coulometry and rapid EIS to generate Li-plating markers and to implement confocal Raman scans of control and HOLE anodes for understanding the Li homogeneity in the anode. Future studies are planned effectively and are consistent with the objectives.

Reviewer 3:
The reviewer suggested that cost analysis should be done with laser partnering that includes anode materials loss and more electrolyte needed to fill the holes. What is the impact of laser patterning to volumetric energy-density impact?

Though successful in this project, fundamental detailed research is needed to better understand why laser patterning works (for example, electrochemical characterization, such as impedance spectra with and without laser patterning, may be needed) and analysis of how the hole laser patterning can help reduce the tortuosity to facilitate fast charging. Those may not be done due to time limitations. However, the reviewer suggested studying the optimization of hole size and number of holes per square unit of anode to understand their impact on battery life and energy density for optimization in the future.

Reviewer 4:
This project needs to justify the costs of implementation of this process over the cost of other processes that can perform the same task of putting structured holes in the anode layer. The process needs to demonstrate that the impact on the structure will not result in a reduction in the tensile strength or slow the speed of the overall layer-cell production speed, which has overall costs implications. There are some concerns that this process, while meeting the goals, could be less cost effective than some processes in place that accomplish the same result.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is aimed at improving the fast-charge capability of Li-ion batteries to charge to greater than 80% of the cell capacity within 10 min. at room temperature, while retaining greater than 80% of initial specific energy of more than 180 Wh/kg over 500 fast-charge cycles. The strategy for achieving XFC capability is to modify the anode morphology with laser patterning to engineer highly regular, cylindrical-pore channels into post-calendared graphite anodes to facilitate permeability of Li ions deep into the anode. Such channeled pores will minimize concertation polarization both in the electrolyte and electrode (anode), reduce anode utilization, and can be implemented using a scalable process compatible with existing roll-to-roll manufacturing. Fast charging is one of desired performance characteristics for EV batteries and will enable a widespread use of EVs batteries, especially if the implementation has no adverse effect of cost or energy densities. According to the reviewer, the project is well designed and well planned and is consistent with the goals of the DOE-VTO program.

Reviewer 2:
There is a need to improve the fast-charge capabilities of vehicle battery systems. This process provides one way to improve the capability of a cell to be fast charged without negatively impacting the cell cycle life or performance.

Reviewer 3:
The project supports the goals for battery fast charging.

Reviewer 4:
The reviewer asserted that XFC objectives were met by this project.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources seemed appropriate to the reviewer, considering the need to build cells and the labor required for experimentation.

Reviewer 2:
The resources are appropriate for the scope of the project.

Reviewer 3:
The resources appeared to the reviewer to be sufficient for the proposed efforts.

Reviewer 4:
The resources provided allow the project to meet its stated milestones within the timeframe identified.

Presentation Number: bat395
Presentation Title: Developing Safe, High-Energy, Fast-Charge Batteries for Automobiles
Principal Investigator: Wenjuan Mattis (Microvast, Inc.)

Presenter

Wenjuan Mattis, Microvast, Inc.

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

67% of reviewers indicated that the project was relevant to current DOE objectives, 33% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 33% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

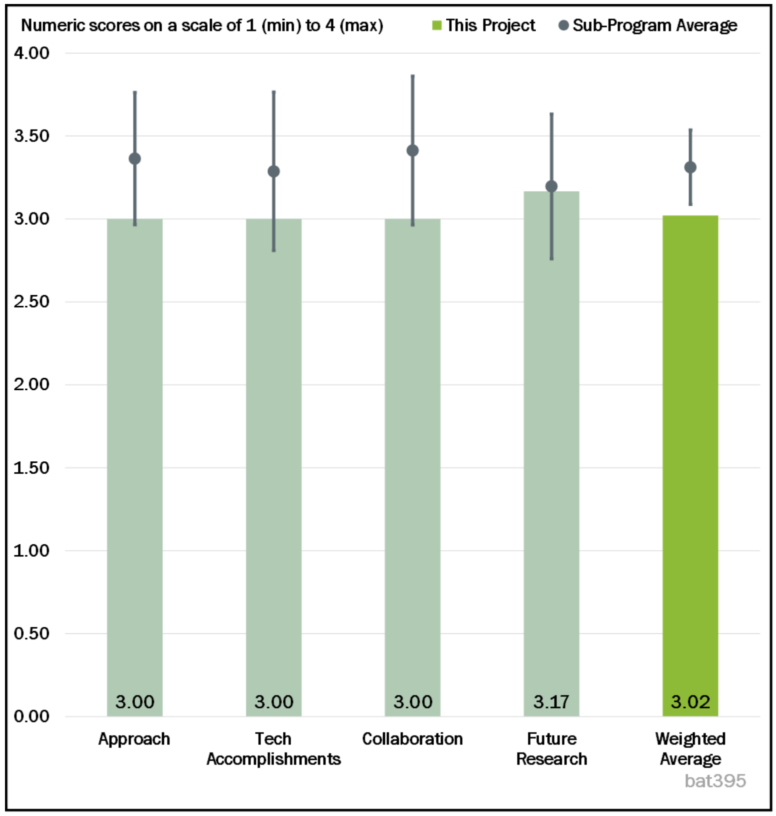

Figure 2-28 - Presentation Number: bat395 Presentation Title: Developing Safe, High-Energy, Fast-Charge Batteries for Automobiles Principal Investigator: Wenjuan Mattis (Microvast, Inc.)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The technical approach addressed fast charging for high energy-density batteries.

Reviewer 2:
Gen-1 had decent fast charge capability. Gen-2 gave much higher energy density at low rates, but its performance was worst in terms of XFC. Perhaps more testing and modeling done prior to cell build to meet the target objectives might have been warranted. Results for Gen-3 appeared encouraging to the reviewer. There is very little emphasis on the anode, which is likely a problem for fast charge.

Reviewer 3:
It appeared to the reviewer that the approach has been focusing on improving the specific energy of Li-ion cells, while the fast-charge capability appears to be a secondary objective. The approach is based on developing new materials for XFC batteries—in particular, high-Ni, full-gradient composition NMC cathodes with and without low impedance electrolytes with selected additives—and incorporating them in automotive-size (larger than 15 Ah) XFC prototype cells. Detailed post-mortem studies were being made to understand the failures in XFC cycling. The nano-rod structure on the cathode surface is expected to improve kinetics (at the cathode). In addition, high-temperature stable separators were being targeted to improve the safety. Again, this is oriented to improve the specific energy rather than fast-charge capability of Li-ion cells.

It was pointed out in previous reviews that this project seems geared toward higher energy-density material improvements, which do not relate to fast charging, and the response and the results are not convincing. Unlike the other VTO projects that focused on enhancing the Li-intercalation kinetics at the graphite anode, this project has been focusing on the cathode with nano-rod surface morphology and surface coatings. As such, the project did not seem to the reviewer to be well integrated with other VTO projects.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The technical progress is reasonable and is aligned with the plan.

Reviewer 2:
The reviewer found the performance in Gen-2 to be somewhat disappointing. Hopefully, Gen-3 will be successful, based on improvements in electrolyte and cathode material.

Reviewer 3:
Good progress has been made in achieving reasonably high (220 Wh/kg) pouch cells that retained 90% of capacity after 500 XFC cycles. The failure modes in the prototype cells during XFC cycling have been identified through detailed analytical studies, including TM dissolution from the cathode, which may be mitigated with surface stabilization of cathode with Mn-Al particles and electrolyte modification. As well, the high-Ni, full-concentration gradient cathode has been scaled up for prototype testing.

Even though there are clear advancements in cathode materials, and continuous improvement both in specific energy and cycling of prototype pouch cells, the reviewer stated that these improvements are not connected with the goal of improving fast-charge capability. The specific energies achieved here in the prototype cells are not significant compared to the commercial cells. Overall, the progress achieved here is only moderate and is relevant to DOE goals.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
According to the reviewer, there is active collaboration with ANL, where all the materials development (new cathode and electrolyte additives) and advanced characterization of materials and post-mortem electrodes were performed. Likewise, there is a successful industrial partnership with BMW in the fabrication of hard-can cells in the development of test protocols relevant to commercial EVS. Microvast will develop thermally stable separators to improve safety during XFC cycling.

Reviewer 2:
The collaboration across the team members appeared excellent to the reviewer.

Reviewer 3:
This is a good collaboration between a DOE National Laboratory and industry.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The future research finishes the cell build with new materials and tests the performance.

Reviewer 2:
There are continued challenges in identifying Li-plating conditions in XFC cells for implementing both material and engineering solutions and in overcoming the diffusional limitations during fast charge. Future plans include fabrication and testing of XFC automotive cells with high capacity by incorporating all the materials developed in this project. It was not clear to the reviewer what the targeted specific energy of the

cells is under nominal cycling conditions in relation to the current baseline cells, which can provide greater than or equal to 250 Wh/kg. Future studies are planned effectively and are consistent with the objectives.

Reviewer 3:
The reviewer commented that the aging study seems behind schedule. Testing with different upper charging voltage limits may be needed for the experimental cell design.

LiDFOB and lithium bis(oxalate)borate may be good additives for the electrolyte to reduce Mn dissolution. The reviewer suggested that other additives may be considered, such as 1% dimethylacetamide and MTMSC if the budget and time allow to do so in the future research.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is aimed at developing safe, high-energy cells using new cathode and electrolyte materials with fast-charge capability and demonstrating XFC cells using both pouch and prismatic, large-format automotive cells. This project was intended to improve the understanding of cell failure during XFC cycling, which would enable EV cars to recharge at similar rates to gasoline vehicles and thus improve convenience for consumers. The reviewer noted that XFC-capable cells may accelerate adoption of EVs, especially for commercial fleet vehicles that could now run continuously. The project is well designed and well planned and is consistent with the goals of the DOE-VTO program.

Reviewer 2:
The project supports the goals for an increase in battery-specific energy density.

Reviewer 3:
The reviewer commented that this project does not seem to be overly targeted on XFC.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the project is not overly funded and, considering the number of cells delivered, is appropriate.

Reviewer 2:
The resources appear to be sufficient for this project.

Reviewer 3:
The reviewer believed that resources are excessive for the project scope.

Presentation Number: bat396
Presentation Title: Enabling Extreme Fast Charging through Anode Modification
Principal Investigator: Esther Takeuchi (Stony Brook University)

Presenter

Esther Takeuchi, Stony Brook University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 33% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

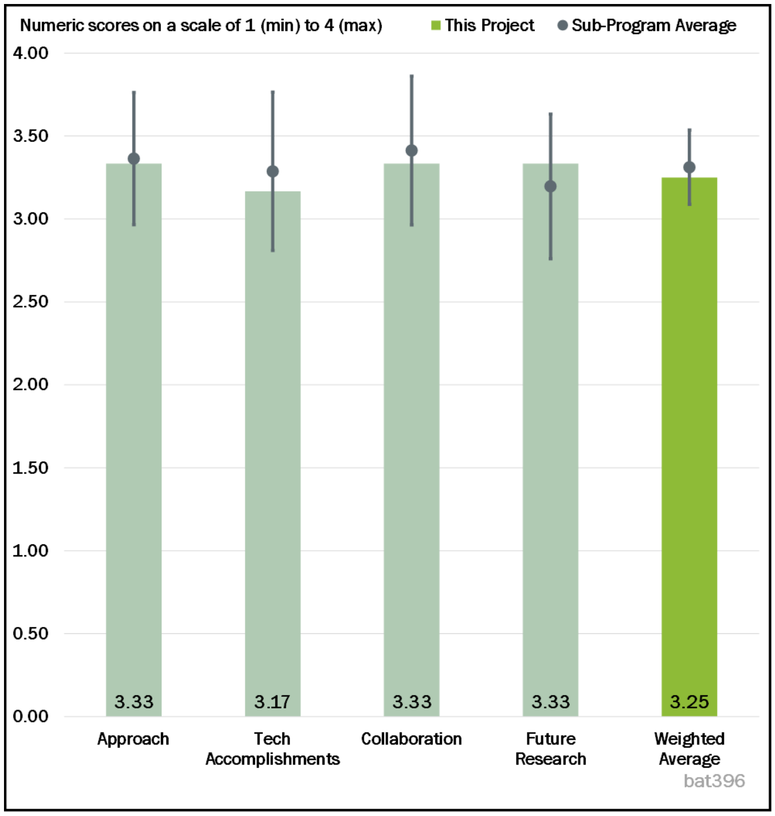

Figure 2-29 - Presentation Number: bat396 Presentation Title: Enabling Extreme Fast Charging through Anode Modification Principal Investigator: Esther Takeuchi (Stony Brook University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project demonstrated precise control of metal coatings that improved performance in terms of reduced performance fade and less Li plating. This targets some of the concerns with fast charging. According to the reviewer, the project was a nice demonstration of the concept to increase Li deposition over-potential.

Reviewer 2:

This project is addressing the barriers of extreme fast charging for EVs and is based on the concept of selectively increasing the over-potential for Li deposition at the graphite surface through electrode-surface treatment with nanometer-scale Cu or Ni films. It was not quite clear to the reviewer how this seems to be working, i.e., if Li is reduced as a metal and diffuses through the Cu or Ni layer. If so, this is bypassing the intercalation, which would be the desired reaction on the graphite anode versus plating. With the volume changes occurring in the graphite anode, it is quite possible that the coating will delaminate during cycling. Possibly coating the particles may be a better alternative. This concept, if successful, is relatively easier to implement and is compatible with current manufacturing methods. Also, verification of this concept is fairly straightforward, with nanometer-scale Ni or Cu layers with optimized thickness on graphite and evaluating the fast-charge characteristics in relation to the baseline.

Detailed surface studies were made to understand the SEI characteristics of the pristine graphite and the Ni- or Cu-coated graphite anodes and to quantify Li deposition on these anodes during fact charging. Even though this concept is easier to implement in practical cells, the effect will not be significant, with only 40 millivolts (mV) and 30 mV of over-potentials for Li deposition on Cu and Ni. Typical anode polarization during fast charging is much higher. This is substantiated by the fact there is considerable Li plating (no doubt less) even on Cu- or Ni-coated graphite anodes. With the coated graphite anodes at optimized thickness, 2 Ah cells will be fabricated and delivered to a DOE National Laboratory for assessment.

Overall, the reviewer commented that the project has been addressing the technical barriers related to fast charging, is well-designed, appears feasible, and may be integrated with other VTO efforts.

Reviewer 3:
The technical approach addressed battery fast charging by anode coating with Cu and Ni.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The technical approach is innovative, and the progress is aligned with the plan.

Reviewer 2:
Good progress has been made in verifying this concept showing reduced Li plating on Ni- and Cu-coated graphite, even though Li plating is not totally suppressed. The type and thickness of the coating were optimized. Detailed studies were made to characterize the surface coating and mainly the SEI that formed on the coated anode, which seems to be similar to the SEI on baseline graphite anodes. The benefit of coated graphite anode was demonstrated with Ni-graphite anodes in single-layer pouch cells on reducing capacity fade, and a 2 Ah cell build containing the coated anodes is being planned. The reviewer opined that it would be interesting to see the three-electrode cell data with different anodes (coated and pristine) to correlate the anode over-potential with the extent of Li plating.

Overall, the progress achieved is reasonable and well directed toward the DOE goals of developing LIBs with high specific energy and good capacity retention during XFC cycling.

Reviewer 3:
At this funding level, the reviewer asserted that one might expect a little more progress. The project did, however, lead to proof of concept in terms of reducing the amount of Li plated and increasing the cell life, which might have a universal applicability not just for XFC. The metal coatings do not increase the charge capability though they do not negatively affect it either.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration across the team members appeared excellent to the reviewer.

Reviewer 2:
The project demonstrates use of resources and expertise across the partner team.

Reviewer 3:
This is a joint program between Stony Brook University and BNL for achieving Cu-Ni coatings and basic electrochemical measurements at the university and extensive characterization studies and cell characterization at the National Laboratory. Plans are underway to collaborate with NREL for computational efforts. The reviewer remarked that collaboration with a cell manufacturer will possibly expedite the development toward demonstration in high specific-energy cells.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future research is on target to accomplish the program objectives.

Reviewer 2:
There are still challenges in understanding the over-potential of surface-treated versus control anodes as a function of charge rate and understanding capacity retention for Cu- and Ni-coated electrodes. Also, the uniformity of the metal coatings will need to be verified using SEM and EDS. In short, the investigations on Li-plating on Ni- or Cu-graphite will be completed under different experimental conditions before finally planning for 2 Ah cells with graphite anodes with optimized metallic coatings for DOE assessment.

Overall, the reviewer indicated that the planned future work is logical and leads to the realization of the proposed technology.

Reviewer 3:
A cost analysis with the developed coating technology for cell production may help to convince battery producers to consider technology transfer. Now that the temperature seems to improve battery capacity at relatively high temperatures (Slide 15), the reviewer suggested that it may be worth the effort to test battery decay for fast charging at higher temperatures (e.g., 50˚C) with the developed cells.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is aimed at improving extreme fast charging by changing the over-potential for Li deposition at the graphite surface through electrode-surface treatment with nanometer-scale Cu or Ni films. The surface coatings will increase the over-potential for Li nucleation and growth and suppress Li deposition at high charge rates; the battery will address the EERE goal (500 6C charge at 1C discharge cycles) without much design modifications to the current Li-ion cells. If successful, this project will enable EV cars to recharge at similar rates to gasoline vehicles and may accelerate adoption of EVs, especially for commercial fleet vehicles. According to the reviewer, the project is well designed and well planned and is consistent with the goals of the DOE-VTO program.

Reviewer 2:
Since Li plating is a very strong concern for XFC, the reviewer asserted that this project is right on target.

Reviewer 3:
The project supports the goal of fast charging for the battery with relatively high specific energy density.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources appear to the reviewer to be sufficient for the proposed efforts.

Reviewer 2:
It would be good to see more published results at the end of this project. Presumably that will follow after completion of the Q8 milestones.

Reviewer 3:
The resources, the reviewer believed, are excessive for the scope of the project.

Presentation Number: bat397
Presentation Title: Titanium Niobium Oxide-Based Lithium-Ion Batteries for Extreme Fast-Charging Applications
Principal Investigator: Sheng Dai (University of Tennessee at Knoxville)

Presenter

Sheng Dai, University of Tennessee at Knoxville

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 33% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

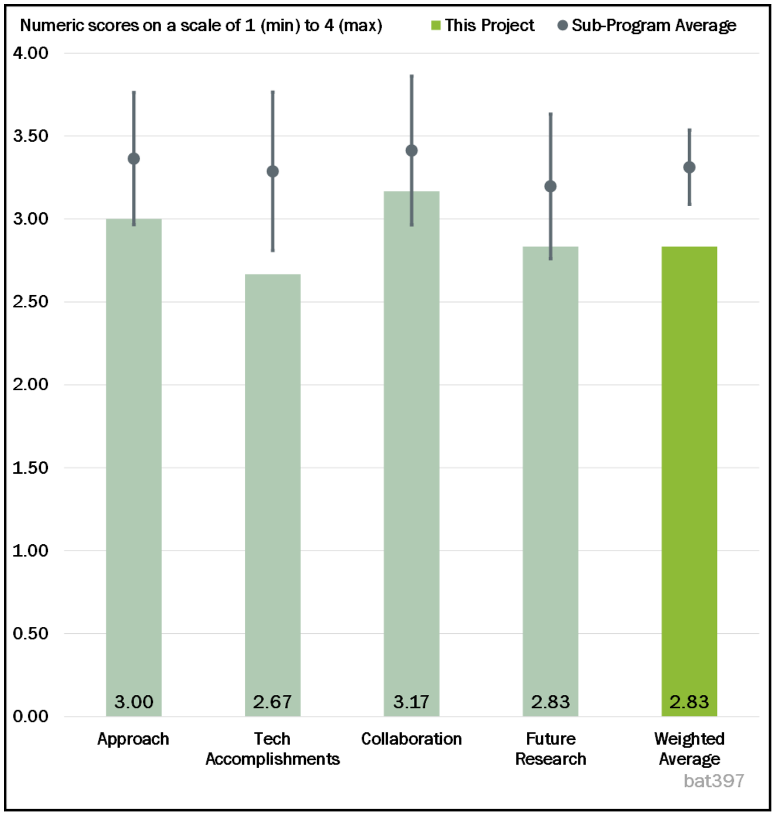

Figure 2-30 - Presentation Number: bat397 Presentation Title: Titanium Niobium Oxide-Based Lithium-Ion Batteries for Extreme Fast-Charging Applications Principal Investigator: Sheng Dai (University of Tennessee at Knoxville)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project addressed technical barriers as envisioned at the beginning by looking at doping and carbon and loading of titanium niobium oxide (TNO).

Reviewer 2:

The technical approach addressed battery fast charging by employing a TNO anode.

Reviewer 3:

This project is attempting to find alternative anode material to overcome the problem of Li plating at high-charge rates. Specifically, TNO with high capacity (250 mAh/g) is being developed, with improved electronic conductivity by metal doping and carbon coating. The approach involves developing methods to synthesize large-scale TNO and demonstrating its cycle life in full NMC622 cathodes using suitable electrolyte additives (new Li malonatoborate salts) in fast charge cycling (XFC). Even though there is an improvement in the capacity of the TNO anode, its capacity is still lower than graphite at nominal rates and, more importantly, its voltage is quite high at more than 1.2 V, about 1 V higher than graphite. With the high anode potential (low cell voltage) and low capacity, the reviewer stated that it is unreasonable to expect high specific energy for this system, as also pointed out in the previous reviews. Even though the TNO anode supports fast charging with minimum polarization (relative to the cathode), the specific energy during XFC cycling is woefully low (130 Wh/kg) and well short of the DOE target.

Overall, the project aims to address the technical barrier of the low energy of Li-ion cells during fast-charge cycling, but is not an appropriate solution, according to the reviewer, and may not be integrated with other VTO efforts in this category.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
In light of the funding level, the reviewer said that the accomplishments and progress are good.

Reviewer 2:
The technical progress is reasonable though some milestones have been delayed. The developed cell may have potential for high-power applications though its specific energy density cannot meet 180 Wh/kg.

Reviewer 3:
Moderate progress has been made in developing the TNO anode as an alternative for enhancing the fast-charge capability of Li-ion cells. Bulk TNO was successfully synthesized without using a templating agent, which provides high specific capacities of 250-300 mAh/g, especially after modification (not mentioned what this is). The electronic conductivity for high-rate performance was improved with different dopants (such as TM doping, Li doping, TM and Li co-doping, and C doping) and coatings. With the modified and doped TNO in three-electrode cells with the NMC622 cathode, the team demonstrated that the anode polarization during fast charge is low compared to the cathode. Finally, large-format 2-Ah pouch cells were fabricated, evaluated, and delivered to DOE using this material.

Even though there is a decent amount of improvement in the TNO anode, the reviewer observed that the overall performance is inadequate, and the specific energy is barely 130 Wh/kg versus the DOE target of 180 Wh/kg. Especially because of the high anode potentials and low cell voltages, the reviewer said that it is very unlikely that the DOE target can be met with this material.

Overall, the progress achieved is reasonable and well directed toward DOE goals, but the improvement in the fast- charge capability is achieved with a severe penalty in the specific energy. Even if it is possible to get to 180 Wh/kg under XFC cycling, the specific energies under nominal cycling conditions will be significantly lower than the current Li-ion batteries.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project appeared to the reviewer to have good collaboration between a National Laboratory and materials suppliers.

Reviewer 2:
The contractor has put together a team consisted of a university and a National Laboratory doing collaboration to attack the technical barriers for cell design capable of fast charging. A further collaboration with National Laboratories and/or industry may be needed to increase cell-specific energy density and cell life, according to the reviewer.

Reviewer 3:
Most of the work in this project—including development of TNO material and electrolyte, battery evaluation, and fabrication and testing of large format pouch cells—is being done at the PI's organization (ORNL). The reviewer saw little collaboration with the material suppliers, TODA America and Conoco Phillips, for NMC622 powders and conductive carbon and also suppliers for the binder polymer.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer hoped to see if a high-energy cathode can be included for higher, cell-specific energy density if there is future research conducted in this direction with TNO anodes.

Reviewer 2:
Unlike other projects, this project has a unique challenge of having to synthesize the anode material in bulk for large- format pouch cells. Additionally, the reviewer emphasized that there is a bigger challenge of low energy density, well below the DOE target because of the low cell voltages. Future work will aim to improve the specific capacity of TNO under high rates using anion doping and substituting for Nb to increase the cell voltage with high-voltage cathodes and to mitigate the gassing with surface coatings. Overall, the planned future work is logical, though it may not lead to the realization of DOE's performance targets for XFC cycling of Li-ion batteries.

Reviewer 3:
Gassing is an important subject to address. Understanding its formation is the first step as laid out by the investigators. Doping strategies might be helpful to improve rates but probably not a great return on investment. Doping to change the voltage is also unlikely to be useful, according to the reviewer.

Volumetric energy density could be an important benefit of TNO. Perhaps use of larger particles is worthwhile to increase this advantage. This technology will never be a leader in terms of specific energy density.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is aimed at improving extreme fast charging by developing alternative anode material to graphite, which is susceptible to Li plating due to the proximity of its potential to Li deposition potential. According to the reviewer, specific objectives are to:

- Develop TNO-based anode materials with high electronic conductivity, high Li diffusivity, and high capacity to meet the requirements of 180 Wh/kg during fast charge (6C) (XFC) cycling.
- Identify new electrolyte additives for good capacity retention (80%) through 500 XFC cycles.

If successful, this project will enable EV cars to recharge at similar rates to gasoline vehicles and may accelerate adoption of EVs, especially for commercial fleet vehicles.

The reviewer stated that the project is well designed and well planned and is consistent with the goals of the DOE-VTO program.

Reviewer 2:
The project supports the goals for battery fast charging.

Reviewer 3:
Using a TNO anode can enable fast charging. The reviewer noted that it is likely difficult to adopt for pure EV owing to lower energy density, but there could be other applications.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources are sufficient for the scope of the project

Reviewer 2:
The resources appear to be sufficient for the proposed efforts.

Reviewer 3:
The reviewer remarked that there is a very small amount of funding considering that full cell builds are done.

Presentation Number: bat398
Presentation Title: Extreme Fast-Charging Lithium-Ion Batteries
Principal Investigator: Edward Buiel (Edward Buiel Consulting, LLC)

Presenter

Edward Buiel, Edward Buiel Consulting, LLC

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 33% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

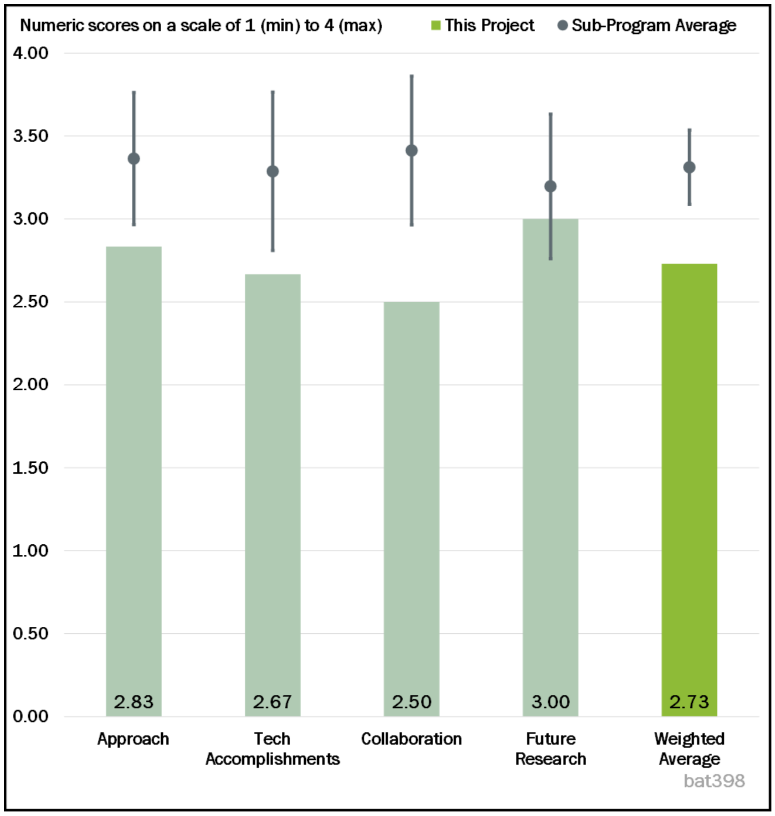

Figure 2-31 - Presentation Number: bat398 Presentation Title: Extreme Fast-Charging Lithium-Ion Batteries Principal Investigator: Edward Buiel (Edward Buiel Consulting, LLC)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Investigators are able to achieve the XFC goals by engineering the anode thickness and choice of electrolyte and cathode. Based on the results, the reviewer commented that the approach is sound and well designed.

Reviewer 2:

The technical approach is appropriate.

Reviewer 3:

This project is attempting to find optimum anode, cathode, and electrolyte compositions and also the cell design to improve specific energy while enabling fast-charge capability. Capacity loss and impedance increase after 350 h were used as diagnostic means for Li plating, as the cells were cycled at various rates from C/10 to 4C. Multiple anode compositions (details not provided on these variations) were combined with two different cathodes: nickel cobalt aluminum oxide (NCA) and NMC622. Cell designs were closely examined to understand the role of tabs in causing non-uniform current distribution and heat dissipation at high charge rates, and new electrode designs were pursued to minimize the tab effects.

This project did not seem to the reviewer to have a clear strategy for the different anode, cathode, and cell variations examined here or was not presented well. Overall, the project aims to address the technical barrier of the low energy of Li-ion cells during fast charge cycling but is not particularly informative and revealing to be integrated with other VTO efforts in this category.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
According to the reviewer, high-rate charging was accomplished per the objective of the project by modifications of the cell chemistry and cell design.

Reviewer 2:
The technical achievement is impressive, but the reviewer said that there is still a gap for the designed cell to meet the specific energy density goal.

Reviewer 3:
Moderate progress has been made in developing the fast-charge capability of Li-ion cylindrical cells by examining multiple anode and cathode variations and cell-design modifications. Capacity loss and impedance increase after 350 h were identified as a diagnostic means for Li plating, as the cells were cycled at various rates from C/10 to 4C. Multiple cells produced with different anode compositions showed limited effect of anode composition on charge rate.

Subsequent variations included reduced anode-coating weight and increased anode density, which resulted in higher charge rates of 6C in Gen-2.5 power cells consistent with DOE XFC test conditions. Further reduction in the anode- coating weight improved the fast charge capacity to 9C in Gen-3 cells. Modified electrode design mitigated the impact of tab location on uniformity in current distribution of heat dissipation. Addition of SiO_x to the anode did not improve the performance in Gen-3 cells.

Overall, the progress achieved is reasonable and directed toward DOE fast-charge goal, but there is no mention of the specific energies from the cells with variations. It was not clear to the reviewer that these cells meet the DOE goals in specific energy, i.e., 180 Wh/kg in XFC cycling with 80% retained through 500 cycles (and high specific energy at nominal rates).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that the project could have benefited from some collaborators with analytical tools and expertise not available to the investigators.

Reviewer 2:
This is a project from Coulometrics LLC with no partners in the project execution.

Reviewer 3:
According to the reviewer, the team would have been strengthened if it had teamed with at least one National Laboratory and/or an established battery OEM to choose appropriate cathode-anode pair and cell format to increase cell specific energy density.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer stated that the proposed final research meets the program objectives.

Reviewer 2:
The project is coming to an end and the only remaining activity is to complete full-cell homologation of proven design improvements for the final report and deliver cells for DOE evaluation.

Reviewer 3:
The reviewer remarked that there is no action proposed in the future plan to meet the proposed cell energy-density goal.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The objective of fast charging Li-ion was achieved.

Reviewer 2:
This project is aimed at improving fast-charging lithium-ion batteries (LIBs) and identifying methods to overcome Li plating on the anode without sacrificing energy density. Specifically, this project has addressed XFS by optimizing the compositions of anode, cathode, and electrolyte anode composition, as well as the cylindrical (18650) cell design. If successful, this project will enable EV cars to recharge at similar rates to gasoline vehicles and may accelerate adoption of EVs, especially for commercial fleet vehicles.

The reviewer stated that the project is well designed and well planned and is consistent with the goals of the DOE-VTO program.

Reviewer 3:
The overall goal of this project supports battery fast-charging research, in the reviewer's opinion.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources are sufficient for the scope of the project.

Reviewer 2:
The funding level is appropriate for the research.

Reviewer 3:
Resources appeared to the reviewer to be excessive based on the project plan but might be okay if a large number of cells were built.

Presentation Number: bat400
Presentation Title: Novel Liquid/Oligomer Hybrid Electrolyte with High Lithium-Ion Transference Number (Hi-LiT) for Extreme Fast Charging
Principal Investigator: Zhijia Du (Oak Ridge National Laboratory)

Presenter

Zhijia Du, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

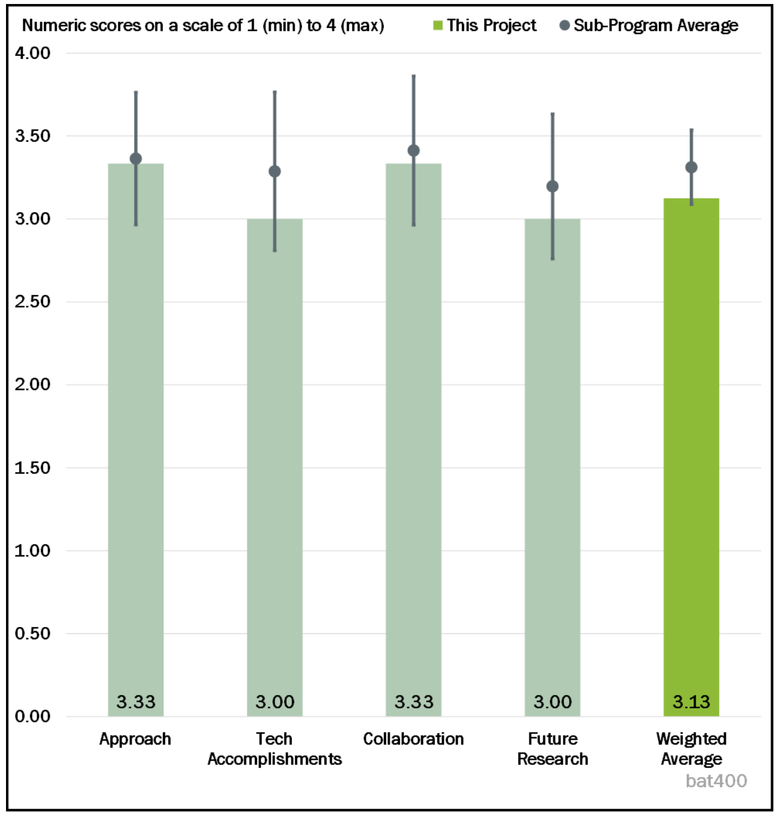

Figure 2-32 - Presentation Number: bat400 Presentation Title: Novel Liquid/Oligomer Hybrid Electrolyte with High Lithium-Ion Transference Number (Hi-LiT) for Extreme Fast Charging Principal Investigator: Zhijia Du (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project is aimed at developing an electrolyte with high transference number for Li-ions and high conductivity to minimize their concentration gradient and improve fast-charge cycling, with the underlying assumption that the Li-ion depletion at the interface is responsible for the low anode efficiency and low specific energy during fast charging. The approach involved the use of different salts (e.g., lithium bis(fluorosulfonyl)imide [LiFSI] and other novel Li salts to slow anion mobility), the use of multi-component solvents to reduce electrochemical (EC)-complexation with Li^+, and the use of electrolyte additives to further immobilize anions, dissociate cations in the electrolyte, and improve their transference number. In order to mitigate the problem of Al corrosion from the imide salt, another protective additive was developed. There is an improvement in the conductivity and in the transference number with the imide salt compared to $LiPF_6$, but the solutions with anion oligomers have lower conductivity to offset the anticipated increase in the transference number. Based on the above considerations, the expected improvement here in fast-charge capability combined with high specific energy will be marginal.

Overall, the project aims to address the technical barrier of the low energy of Li-ion cells during fast-charge cycling. The reviewer said that the project is well designed and feasible and may be integrated with other VTO efforts in this category.

Reviewer 2:
The reviewer called the experimental program well designed. Understanding differences in transference number is important for fast charging. Some method to rapidly screen might be appropriate to find additives and new salts.

Reviewer 3:
The technical approach aims at battery fast charging with novel electrolyte design.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer indicated that the technical progress is impressive and is aligned with the plan.

Reviewer 2:
Investigators made substantial progress and identified LiFSI as a promising alternative for XFC. There is good documentation of results through publications, according to the reviewer.

Reviewer 3:
The reviewer commented that good progress has been made in demonstrating improved fast-charge capability with electrolyte-containing LiTFSI salt and additive to mitigate Al corrosion. Possibly the increase in the cell temperature during fast charge favors the LiTFSI salt over $LiPF_6$. Optimum salt concentration was identified (1.5 molarity [M]) both for fast-charge capability and capacity retention during XFC cycling. The 0.5 Ah pouch cells containing the ORNL electrolyte formulation had higher energy density and better capacity retention than the baseline Gen-2 electrolyte. Projected energy densities to 50 Ah meet the DOE goals but are yet to be demonstrated in large-enough cells. Also, a good baseline would be a commercial EV cell, both in terms of specific energy during XFC cycling and normal cycling rates, rather than a laboratory pouch cell with a Gen-2 electrolyte. The gain in the transference number (not shown here) with the addition of anion oligomers will be offset by the reduction in the conductivity.
Overall, the progress achieved is reasonable but not to the expected level as the project is completing this year.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The team worked well together to obtain results utilizing expertise across institutions.

Reviewer 2:
The reviewed noted that there are several collaborators on this project, which is led by ORNL: another DOE National Laboratory (ANL), multiple universities (University of Alabama at Huntsville, Virginia Tech, and Purdue University), and also a partner in XALT Energy.

Reviewer 3:
The collaboration across the team members appeared sufficient to the reviewer.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
It was not clear to the reviewer why testing of oligomer salt is proposed since it has lower performance relative to LiFSI. Other than that, the proposed work is on target to accomplish project objectives.

Reviewer 2:
There are a few outstanding activities to be completed in the next few months, which include evaluating more electrolyte additives and Li oligomer salts during fast charge; repeating with higher electrode loadings with the new electrolyte; performing post-mortem on the cycled cells for Li plating; and completing the deliverable of 2 Ah cells. Overall, the reviewer described this project as well aligned with DOE goals, but the progress achieved toward these goals is only moderate.

Reviewer 3:
Lithium plating seems to be not the only problems causing cell-capacity decay. A cell with 1.5 M molarity seems to have more Li plating but has less capacity decay compared to those with 1.75 M and 2.0 M (Slides 9 and 10). This may be due to electrolyte decomposition or resistance change with different LIFSI molarity and additive.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Electrolyte is important to XFC cells. This project identified new formulations with improved performance toward the objective.

Reviewer 2:
This project is aimed at developing a new electrolyte for Li-ion cells with high transference number for Li ions to minimize the Li^+-ion concentration gradient during fast charging. Specifically, the target is to develop an electrolyte wherein the transference number is increased from 0.36 to 0.75, while maintaining a relatively high conductivity of 4-10 mS/cm. With this electrolyte, it was expected that the realized specific energy could reach 180 Wh/kg and at least 80% of that is retained after 500 fast-charge cycles. If successful, this project will enable EV cars to recharge at similar rates to gasoline vehicles and may accelerate adoption of EVs, especially for commercial fleet vehicles.

The reviewer indicated that the project is well designed and is consistent with the goals of the DOE-VTO program.

Reviewer 3:
The project supports the goal of fast charging for the battery with relatively high, specific energy density.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the resources are about right.

Reviewer 2:
The resources are sufficient for the scope of the project.

Reviewer 3:
The funding level for this project is appropriate, according to the reviewer.

Presentation Number: bat401
Presentation Title: Advanced Electrolytes for Extreme Fast Charging
Principal Investigator: William Chueh (Stanford University)

Presenter

William Chueh, Stanford University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 33% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

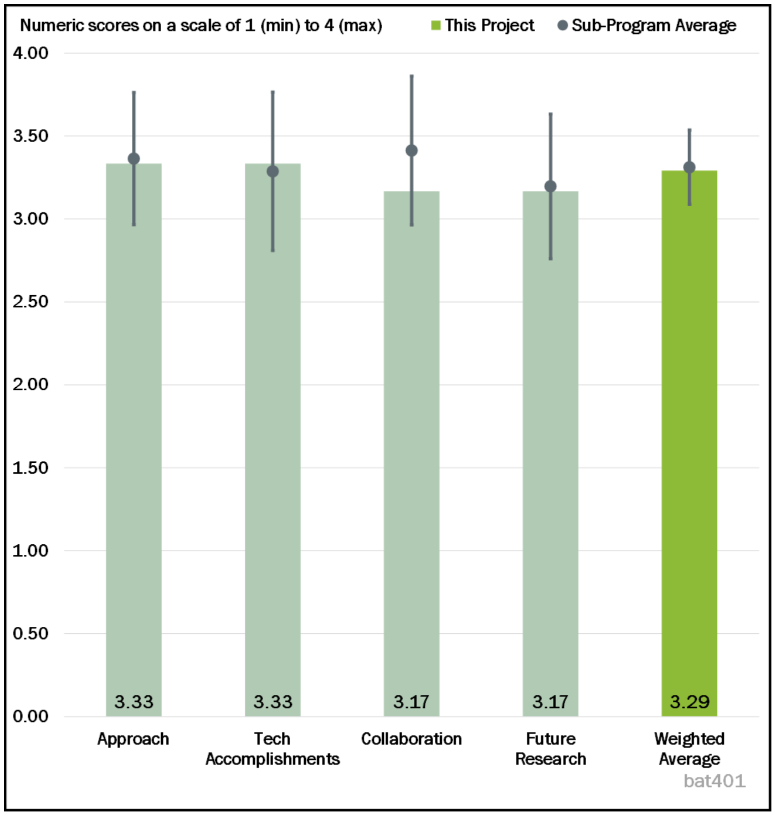

Figure 2-33 – Presentation Number: bat401 Presentation Title: Advanced Electrolytes for Extreme Fast Charging Principal Investigator: William Chueh (Stanford University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the technical approach addressed battery fast charging with an advanced electrolyte and four-step charging protocol.

Reviewer 2:

This project is aimed at developing an advanced electrolyte that can enable fast charging at 6C without the complications of Li plating at the anode, which is detrimental to its subsequent performance. Additionally, the charging protocol is being optimized, and the effects of fast-charge cycling on the electrodes are being analyzed using in-situ X-ray and ex-situ cryo-EM characterization. Electrolyte improvement is based on modifying the electrolyte bulk properties, including conductivity, desolvation kinetics using co-solvents (methyl acetate), and modifying the interfacial (SEI) properties using additives (FEC and two other additives).

It was not clear to the reviewer what the rate-determining step is, i.e., desolvation kinetics or diffusion across the SEI and to what extent desolvation kinetics are improved with the methyl acetate (MA) co-solvents. Electrolytes with MA additions have poor high-temperature resilience, which may be a factor during fast charging. X-ray microscopy and diffraction were used for detecting Li plating, and cryo-EM was adopted to probe the location of Li plating and understand SEI. In parallel, simulations were made for the voltage profile during fast charge.

The approach adopted here is fairly routine and lacks sufficient novelty in terms of electrolyte modifications. Overall, the project aims to address the technical barrier of the low energy of Li-ion cells during fast-charge cycling. According to the reviewer, the project looks well designed and feasible and may be integrated with other VTO efforts in this category.

Reviewer 3:
The project has shown steady improvement in improving fast-charge acceptance and is nearing the goal at about the half-way mark of the project. Li plating is observed on the graphite.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project has met the technical goals and is aligned with the plan.

Reviewer 2:
The project is on track in terms of improved rate acceptance. Li plating has been observed. The reviewer suggested that perhaps more documentation of the results should be done in the literature.

Reviewer 3:
The reviewer found that good progress has been made in demonstrating improved fast-charge capability with electrolyte modifications by using MA co-solvent, FEC, and other electrolyte additives and higher concentrations of salt. With these modifications, the percentage-charge capacity is close but short of the DOE target. Interestingly, the baseline electrolyte was made to look much worse than it should be, which makes the improvement more significant for the modified electrolyte. The use of MA co-solvent will hurt the high-temperature (55ºC) resilience of the batteries, which is also a performance requirement for EV batteries. Both XRD microscopy and cryo-EM were used to study Li plating and SEI formation, though it was not quite clear to the reviewer what additional insight was gathered. It was inferred that the electrolyte mass transport is no longer limiting cell performance, which is not consistent with many of the other fast-charge efforts where enhanced Li transport in the electrolyte has been shown to improved fast-charge capability.

Overall, the reviewer noted that the progress achieved is reasonable around the midpoint of this project.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer asserted that the collaboration across the team members is excellent.

Reviewer 2:
There are collaborations within the lead organization (Stanford University) and the Stanford Synchrotron Radiation Lightsource, along with the ANL Advanced Photon Source, and Dr. Koch from Covalent Associates, one of veterans in the field of Li-ion battery electrolytes.

Reviewer 3:
The reviewer noted that the expertise of the various collaborators has been utilized to build cells, measure their performance, model the cells, develop new electrolyte formulations, and do analytical work on the graphite anode to show Li plating.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
There are a few challenges in the next year, i.e., to translate single-layer performance and cycle life to multi-layer cells. Future studies will therefore focus on optimizing the charge protocol to improve 6C charging,

utilizing X-ray and electron characterizations to assess electrolyte effects on SEI thickness and lithium plating during fast charging, and optimizing the rate capability and cycle life in multi-layer cells.

Overall, the reviewer found that the future work is logical and addresses one of the technological barriers of Li-ion batteries, i.e., fast charge with high percentage capacity (80%) and good capacity retention (80%) through 500 XFC cycles, consistent with DOE goals.

Reviewer 2:
The reviewer suggested that some effort to reduce Li plating should also be included.

Reviewer 3:
The reviewer commented that cell Wh/kg change with cycle life should have been provided to illustrate the research progress. Additionally, it is suggested the impedance data be provided to show the conclusion that increased impedance is responsible for capacity decay.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is targeted toward the program goals to achieve XFC.

Reviewer 2:
This project is aimed at developing an advanced electrolyte and identifying suitable charging protocols that enable XFC on thick graphite-based anodes. With the need for high specific energies, the electrodes in Li-ion cells tend to be thicker and dense, which also pose a significant barrier to XFC (6C) also required for EV batteries. At these high charge rates, there is a greater propensity for Li plating, which leads to a rapid performance decay. It is thus challenging to realize 180 Wh/kg during fast charge and to retain 80% after 500 fast-charge cycles. If successful, this project will enable EV cars to recharge at similar rates to gasoline vehicles and may accelerate adoption of EVs, especially for commercial fleet vehicles.

According to the reviewer, the project is well designed and is consistent with the goals of the DOE battery program.

Reviewer 3:
The project supports the goal of fast charging with the designed high-energy-density cell.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Considering the number of cells built and the work done, the resources seemed appropriate to the reviewer.

Reviewer 2:
The funding resources appear to be appropriate for the proposed efforts.

Reviewer 3:
The reviewer found the resources to be excessive for the scope of the project.

Presentation Number: bat404
Presentation Title: Direct Fluorination of Disordered Rock Salt Cathode Oxides: Synthesis and Characterization
Principal Investigator: Jagit Nanda (Oak Ridge National Laboratory)

Presenter

Jagit Nanda, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

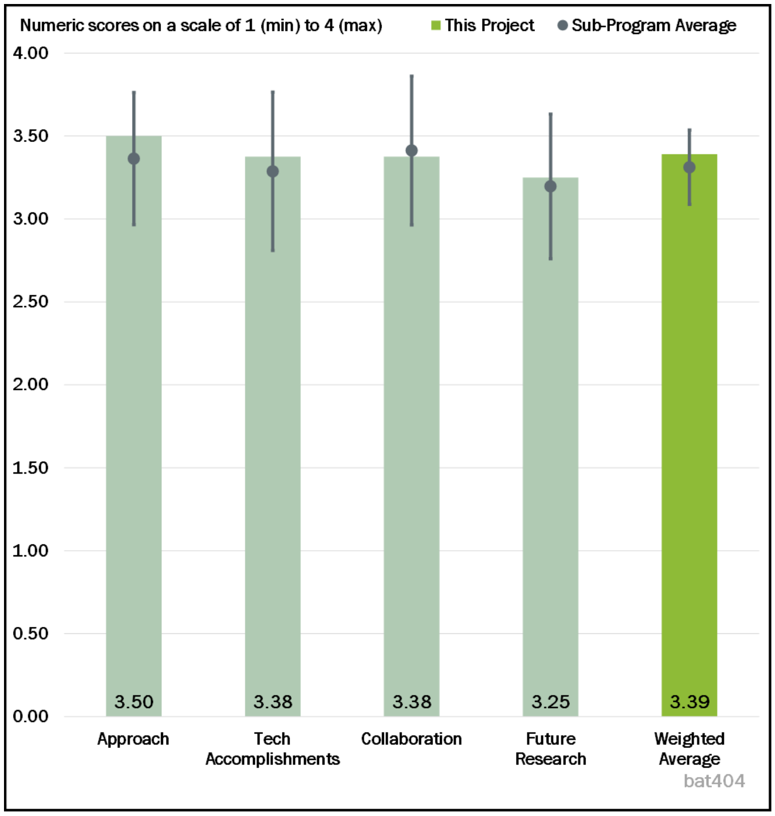

Figure 2-34 - Presentation Number: bat404 Presentation Title: Direct Fluorination of Disordered Rock Salt Cathode Oxides : Synthesis and Characterization Principal Investigator: Jagit Nanda (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Direct fluorination of DRX cathode oxides is an interesting new approach, according to the reviewer.

Reviewer 2:

The project team has presented a variety of possibilities of incorporating F into the DRX cathode structure. It has done excellent work identifying surface F (LiF films) versus bulk (oxyfluoride) and correlating those analytical results with electrochemical performance. The approach combines synthesis and optimization of DRX powders with and without F with strong emphasis on analytical characterization.

Reviewer 3:

The team addressed the solid background, approach, and strategy to explore F-DRX materials. The reviewer commented that direct fluorination is an innovative and challenging approach. Based on the presentation, there are three different approaches to enhance the F content. The reviewer said that it would be good to design a matrix to evaluate the input synthesis methods and output characterization and performance variables to understand the fluorination impact.

Reviewer 4:

The PIs address important barriers to the high-density, cobalt-free cathode. The group has devised scalable synthesis followed by F solubility optimization. Rock salt is a stable crystal structure with likely high stability.

However, the reviewer asserted that the use of Nb-type, rare-earth materials is questionable. This year the group has focused on Ti.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The team has identified a variety of routes, such as direct fluorination of TM oxides as precursors for DRX powders versus direct fluorination of DRX powders. Synthetic variables to incorporate F into the DRX cathode powders were also analyzed. The reviewer commented that one interesting finding was that short-range ordering induced by F content could play a role in Li transport. The NMR results that can clearly identify the LiF surface signal were important. Similar results were confirmed with EM and electron energy loss spectroscopy (EELS).

Reviewer 2:
The reviewer indicated that the team is on track with milestones. The understanding of what F does to the local structure is useful for this material to move forward. The combination of the theoretical modeling with the experimental work provided a clear understanding of the phenomenon, according to the reviewer.

Reviewer 3:
The utilization of neutron PDF for short-range order in DRX structures provided useful information. It was a well-planned study with reasonable accomplishments on direct fluorination as an alternative method to increase F content in DRX structures. The direct fluorinated of Li-Ni-Ti-Mo oxide materials provided a coating-like structure on the surface. The reviewer stated that it would be helpful to know the stability of the fluoride shell upon charging-discharging. Despite the low performance on direct fluorination of LMNOF material, the team provided the mitigating process to overcome in the future.

Reviewer 4:
Results show the importance of F content and offer useful new insights. The reviewer did not understand the slide showing how direct fluorination of pre-fluorinated DRX cathodes exhibited poor performance. Unfortunately, the video was muted so the reviewer failed to fully grasp the significance of this result.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
According to the reviewer, collaboration seems to be fully implemented between the University of California at Santa Barbara (UCSB) (for NMR), the University of Tennessee (for fluorination), and PNNL (for EM).

Reviewer 2:
The team has satisfactory collaboration.

Reviewer 3:
The reviewer stated that there is good collaboration.

Reviewer 4:
The PI indicated the collaboration and contributions from other team members is going well; that was clear to the reviewer in following the presentation. However, as the overall DRX project moves across several teams, the development process can be improved by stronger coordination that effectively utilizes and integrates learnings from other team members.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Optimization of alternative synthetic routes, such as sol-gel, molten salts, and co-precipitation routes, were proposed. The exploration of new F precursors is also mentioned by the presenter.

Reviewer 2:
The reviewer stated that this is an extension of the continuing work.

Reviewer 3:
The proposed future work seems relevant.

The reviewer did not fully understand the value of developing alternative synthesis methods to produce DRX cathodes.

Reviewer 4:
While the findings in the direct fluorination on lithiated DRX are not all encouraging, the team proposed two different routes to fluorinate the DRX materials. In the solution-based method, the material can benefit from better mixing at the atomic level, but the fluorination process was still unclear to the reviewer. The solution-based method has the potential to control the morphology. It would be interesting to know if the direct fluorination changes the morphology of DRX or forms the coating on the surface.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The novel DRX materials research is well aligned with DOE aims for the new SOA LIB system with a Co-free cathode.

Reviewer 2:
It supports the overall DOE objective as the DRX powders studied by the team contain no Co in their structure.

Reviewer 3:
The work will help with the DOE goal of a sustainable and scalable high-energy cathode.

Reviewer 4:
The project is relevant to DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The team provides the unique neutron PDF technique to understand structure order and its relationship with Li transport. The team shows enough resources to complete future plans.

Reviewer 2:
The team has adequate resources.

Reviewer 3:
Resources are sufficient.

Reviewer 4:

The reviewer remarked that the resources may not be sufficient in the future if a scale-up of one of the `productions processes has to be implemented.

Presentation Number: bat405
Presentation Title: Advanced Microscopies of Next-Generation Lithium-Ion Battery Cathode Materials
Principal Investigator: Chongmin Wang (Pacific Northwest National Laboratory)

Presenter

Chongmin Wang, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

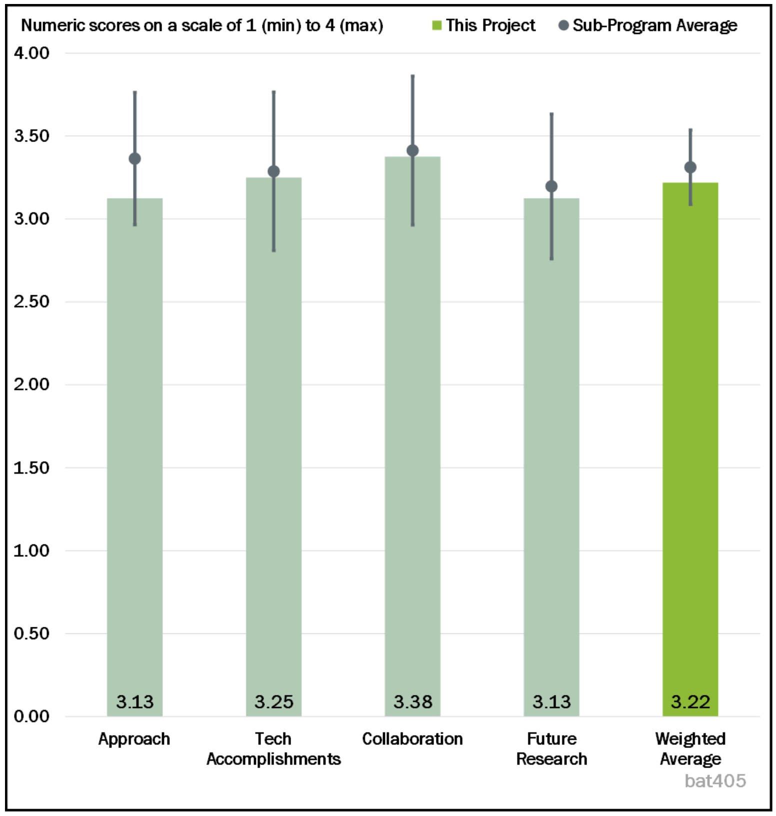

Figure 2-35 - Presentation Number: bat405 Presentation Title: Advanced Microscopies of Next-Generation Lithium-Ion Battery Cathode Materials Principal Investigator: Chongmin Wang (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that this project disclosed a very interesting finding: by using fast Fourier-transform filtering techniques based on atomic-resolution STEM imaging, the team found ordering patterns (on DRX materials) that can correlate to Li-percolation channels. These characterizations are being integrated with new materials and theoretical work to guide in the design of new cathode materials.

Reviewer 2:

This project focuses on the microscopy studies of the Li-ion cathode materials. The project will help build the fundamental understanding of the modes of cathode failure. EELS and EDS atomic-level techniques are employed.

Reviewer 3:

The reviewer remarked that using advanced microscopy to understand disordered rock cathodes is useful and a relevant approach.

Reviewer 4:

According to the reviewer, the work indicated the overall barrier for material research but did not address how to overcome the current barrier technically.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The accomplishments are relevant and reasonable within scheduled milestones. The accomplishments started on NMC811 and moved to another two DRX materials (LTMOF and lithium transition metal oxide [LTMO]). Comparing LTMOF and LTMO is a great discovery and shows that long-cycled LTMOF does not have an obvious degraded surface. However, it was unclear to the reviewer about the fluoride part. This would be helpful to show if fluoride encountered any change in the LTMOF material. In the current results, LTMOF also showed O loss. It would be interesting to know if other F-DRX structures still have this transformation or similar structure evolution.

Reviewer 2:
The reviewer found this to be a very interesting approach to study surface reactivity of these cathode material. The in situ TEM observation of surface reactions is showing promising results. The cathode-air interface may be of critical importance during storage of these powders. The reviewer noted that H_2O vapors seem to trigger the chemical delithiation of NMC cathode powders. In a production facility, that could be a critical variable that has to be considered. The investigation of the cation-ordering on DRX materials (that contains no Co) is also extremely important and is being thoroughly investigated by the team. Bulk and surface changes observed on these DRX cathode powders detected by TEM are also great accomplishments presented by the PI.

Reviewer 3:
The images obtained for NMC811 and its various boundaries are interesting. With these atomic surface-level analyses, it was not clear to the reviewer if the full picture in bulk depths is obtained. What if the sample preparation methods alter the surface and give misleading information?

Reviewer 4:
The reviewer said there is good progress to understanding the ordering in DRX.

TEM data showing that cathode-air interfacial reaction depends on Ni concentration are an interesting insight. The reviewer was not sure what the main implication is.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer found the team and its collaboration to be excellent.

Reviewer 2:
Collaboration between the different teams seems to be great. Interactions between LBNL, ANL, ORNL, Hummingbird Scientific, Thermo Fisher Scientific, and the Battery Research group at PNNL seemed to be well coordinated to the reviewer.

Reviewer 3:
There was good collaboration. The group should complement their experimental work with molecular modeling to get a deeper understanding.

Reviewer 4:
The overall DRX projects involved several National Laboratories and academic institutions. The PNNL team established the advanced microscopy approach to reveal the structural and chemical evolution. While the DRX materials involved a wide range of elemental combinations and most of the materials are still under development, the reviewer suggested that the project would be more comprehensive if it indicated the material resources and coordinated with other findings.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
For general low-Co and Co-free materials, the reviewer stated that the PNNL team proposes a clear future approach. As DRX material was proposed to have higher stability and less O loss, it would be good to apply the PNNL techniques to other DRX materials and unveil F impact on the DRX. The other teams' presentations indicated that the selection of electrolytes could be a factor affecting the cycled DRX structure, which could be another approach to include in the future plan.

Reviewer 2:
The reviewer noted that the study related to the nature of the ordering in these DRX powders (short-range order) seems to be of critical importance. The atomic-level investigation by using in situ and environmental TEM (ETEM) techniques should increase the level of understanding.

Reviewer 3:
This is an extension of the current work.

Reviewer 4:
Proposed future effort is adequate.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Low-Co and Co-free cathode materials are current interests in the DOE-VTO plan. The project is highly relevant to the DOE goal.

Reviewer 2:
This project supports the overall DOE objectives as the DRX powders under study contained no Co.

Reviewer 3:
The results will help the understanding of the fate of cathode material for its rational design.

Reviewer 4:
The project supports DOE goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The team presents the ex situ and in situ TEM and related microscopy techniques to study low-Co and Co-free cathode materials. The reviewer stated that the resources are adequate for the scope of the project.

Reviewer 2:
The team has access to a SOA microscopy facility.

Reviewer 3:
Resources are sufficient.

Reviewer 4:
The reviewer asserted that the project may need additional support if the production process for the DRX materials requires scale up.

Presentation Number: bat406
Presentation Title: Disordered Rocksalt Transition-Metal Oxides (TMOs): Synthetic Strategies
Principal Investigator: Guoying Chen (Lawrence Berkeley National Laboratory)

Presenter

Guoying Chen, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

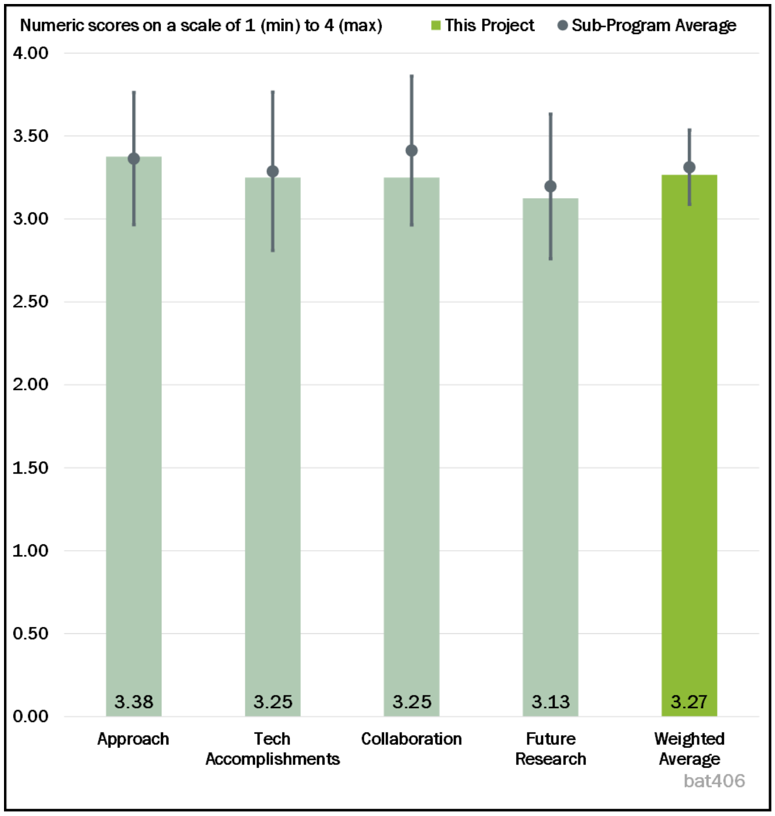

Figure 2-36 - Presentation Number: bat406 Presentation Title: Disordered Rocksalt Transition-Metal Oxides (TMOs): Synthetic Strategies Principal Investigator: Guoying Chen (Lawrence Berkeley National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach seemed to the reviewer to be well designed. The team has focused on DRX materials that contains F. Since F improves many important electrochemical variables in these powders, the team is exploring synthesis conditions to improve this type of cathode materials to increase F content. Powders are electrochemically tested and analyzed to get a mechanistic understanding at the atomic level.

Reviewer 2:

Focusing on synthesis conditions to prepare DRX materials with optimized performance is a promising approach to advance this interesting new material.

Reviewer 3:

The team successfully obtained two out of three proposed DRX materials. Research and development (R&D) and scientific material studies are well designed from fundamental structure to bulk properties. DRX is a new class of cathode materials. The reviewer commented that the current presentation did not always clearly address the technical barriers and approach, specifically the area that the team contributes to while the overall DRX project evolves.

Reviewer 4:

This project focuses on the DRX materials with its synthesis strategies and characterization. The material does provide an alternative to the Co-containing NMC cathode. However, for the new elements, the reviewer asserted that the PI needs to make sure that they are sustainable (e.g., Nb supply concerns).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer observed well-addressed accomplishments on exploring the new materials with synthesis approach and basic material and electrochemical properties for LMNOF and LMTOF.

LMNOF materials gained more attention on material-wide studies including determining voltage-cycling stability, discovering the low conductivity, and determining the F solubility in the current synthesis approach. The reviewer stated that it is a reasonable approach to modify the milestone to determine the F impact on the structure and electrochemical performance. The product from different F contents resulted in different morphology and size. The reviewer said that it would be interesting to know if morphology would be a factor impacting material and electrochemical properties, such as surface properties, packing density, or long-term stability. Also, as the team mentioned, the electrolyte could be a factor to optimize the performance and surface characteristics on DRX materials; this could be a future study or collaboration with an electrolyte expert group in the future.

Reviewer 2:
The reviewer mentioned that the results with the fluorinated cathode powders are very interesting. The team found a variety of positive electrochemical results when working with fluorinated DRX cathode powders. Among the many improvements observed with the fluorinated powders are that the capacity fade is less severe, and stability is increased at higher voltage cycling with fewer severe surface and bulk chemical changes.

Reviewer 3:
The team is making good progress on its milestones. Adjustment was made to expand on the F-content issues. The reported chemo-mechanic behavior and single-particle tomography were interesting to the reviewer.

Reviewer 4:
There is good progress to understanding how high-voltage cycling reduces stability and how carbon additives improve conductivity. The improvement strategy focusing on high F and low Li-TM ratio seemed promising to the reviewer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This is a well-coordinated project. It seems there is a very good interaction between LBNL, ORNL, PNNL, and UCSB.

Reviewer 2:
The reviewer said that this is a high-quality team and has good collaboration.

Reviewer 3:
The team has members with the required skills.

Reviewer 4:
This DRX project involved several National Laboratories and universities, but the contribution and communication from other project teams were unclear to the reviewer. The project would be clearer if it showed more details on the collaboration between teams. While there is lack of details on coordination from other partners across the project teams, the team has shown the capability to execute the project. It would be great to know if the synthesis approach is optimized based on the feedback from other project teams.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Further studies to get a better insight on cycling stability at higher voltages are very important, and the team planned to focus on that area. Increasing the electronic conductivity of these materials is also of great importance.

Reviewer 2:
The proposed future research is well planned.

Reviewer 3:
The reviewer said that this is an extension of the present work.

Reviewer 4:
The project's proposed future research is effective. The reviewer noticed that the TNTMOF materials have not been discussed this year. It would be helpful to know if this material will be included in the future plan.

One of the milestones shifted to optimize the F content and investigate electrochemical capability. Although it is interesting to see the F-DRX study, the reviewer indicated that it would be good to know if the team will consider it in the future. If the production of DRX materials can scale up gradually as in the original plans, it would be useful to study in the larger scale of battery testing and studies.

In the synthesis area, the synthesis approach mainly uses the solid-state method to obtain the DRX structure. Would the team consider the solution method in the future? The solution-based synthesis approach could be easier to scale up in the future.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is very relevant for the overall DOE objectives since these powders—with no Co content—show great electrochemical potential in terms of electrochemical capacity.

Reviewer 2:
The reviewer said that the study of DRX materials is well aligned with the DOE target for the development of novel cathode materials.

Reviewer 3:
The work is relevant to achieving the DOE targets.

Reviewer 4:
The project is relevant to DOE objectives

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The team shows the ability to achieve high-quality results within the timeline and with cross-team collaboration.

Reviewer 2:
The team has access to needed resources.

Reviewer 3:
Resources are sufficient.

Reviewer 4:
The reviewer stated that resources seems to be sufficient; however, the team may need additional support if the project moves toward scale- up of a process to produce larger amounts of cathode powders.

Presentation Number: bat411
Presentation Title: Aerosol Manufacturing Technology for Production of Low-Cobalt Lithium-Ion Battery Cathodes
Principal Investigator: Toivo Kodas (Cabot Corporation)

Presenter

Peter Aurora, Cabot Corporation

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

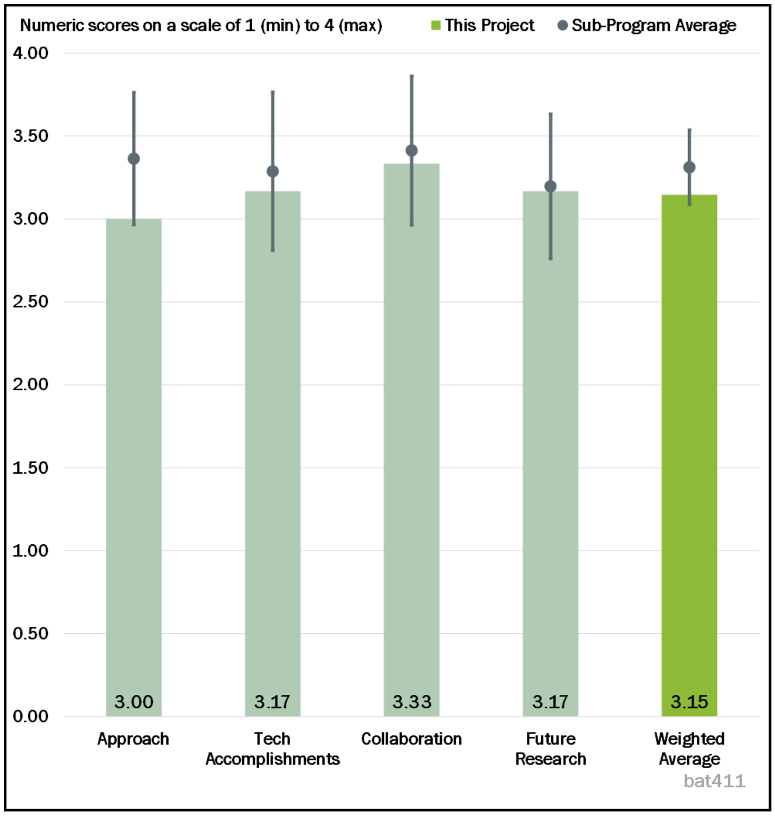

Figure 2-37 - Presentation Number: bat411 Presentation Title: Aerosol Manufacturing Technology for Production of Low-Cobalt Lithium-Ion Battery Cathodes Principal Investigator: Toivo Kodas (Cabot Corporation)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Developing a viable, alternative approach to cathode-material production appeared to be a worthy goal, and this project addresses that issue in an effective way. The reviewer’s only criticism is that the project would benefit from more benchmarking. While the material is well characterized from a physical and performance point of view, there is no direct comparison to a commercial standard. This is at least possible in the NMC811 system that is used as an example of the production capability. In the same way, there is no legitimate discussion of cost projections from this project although cost targets are prominent in the goals.

Reviewer 2:

The overall performance of reactive-spray technology (RST) for making high-Ni NCM is good. However, the poor particle distribution could lead to variable cell performance and faster fade. From the SEM images, it looked to the reviewer like small particles, which would lead to higher surface area and more CEI formation. This ultimately needs to be addressed before commercialization.

Also, it would be good to see a cost breakdown of the RST–flame-spray pyrolysis (FSP) processes versus the conventional co-precipitation method. It was hard for the reviewer to understand the relevance of trying to introduce a new technology for making materials.

Reviewer 3:

Manufacturing processes and conditions are important in the production of the cathode materials. The presented information has no data on how the proposed RST and FSP methods can reduce the cost of cathode manufacturing. In fact, the reviewer asserted that the annealing temperature of 750°C is in the same range as for the cathodes manufactured using solid-state technology. In addition, the proposed methods include extra steps and some result in waste-stream generation. What is the environmental impact of these technologies?

The reviewer observed that it is important to compare the results to the commercially used materials. For example, what will be the impact of small pore-size distribution (PSD) on safety and stability? The industry is evaluating the possibility of using single-crystal cathodes for this reason.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
As stated earlier, while the reviewer would like to have seen more benchmarking, the tasks as proposed were completed in a highly competent manner and the technical work displayed was high quality and comprehensive.

Reviewer 2:
The team has made a number of samples of different compositions. The reviewer commented that it will be interesting to see more systematic studies toward optimization of the physical properties to demonstrate the benefits of the selected techniques. Once again, there is a need to run benchmarking tests to demonstrate advantages.

Reviewer 3:
Performance of the RST-FSP methods for high-Ni cathode active materials (CAMs) is decent. However, significantly more work is needed to improve the PSD. This is likely needed before the commercialization of the cathode material.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer found the team collaboration to be strong. It is sending the CAM materials to Saft where the company is building the pouch cells and doing the necessary testing.

Reviewer 2:
The team is definitely well aligned.

Reviewer 3:
Collaboration appears appropriate for the stage of the project. Collaboration will need to increase in scope as the project matures.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Most of the future goals are appropriate. The reviewer had some question about the ability of the participants to effectively address the goal of optimizing the actual cathode-coating procedure, however. This could possibly benefit from a more suitably qualified partner.

Reviewer 2:
The proposed plan is to scale up the RST method. However, the reviewer thought the challenge remains in the method of creating the small particle size. The reviewer suggested going back and revisiting how to get better particle uniformity before focusing on scale-up.

Reviewer 3:
The future work is focused on optimization of the synthesis conditions, cell testing, coating, etc., which is a standard route for any new development. The team must focus on answering question regarding the cost, including waste-stream recycling.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The synthesis of high-Ni $Li_{1+w}[Ni_xCo_yMn_z]_{1-w}O_2$ (NCM) is important, and methods to reduce the cost and boost cell performance are needed. This project aims to address those issues.

Reviewer 2:
The development of newer variations of experimental low-Co structures requires a capability to produce at reasonable levels. Even if this project does not become cost viable at a large commercial level, it may very well be the bridge process required to produce reasonable scale-up volumes of experimental material.

Reviewer 3:
Cost reduction is extremely important for the industry growth. However, it was not clear to the reviewer how this project could achieve the objective.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the team has sufficient resources to complete the project along with know-how from the National Laboratory and testing from Saft.

Reviewer 2:
Resources appear sufficient for the time being. Broader participation with other collaborators in the future should be anticipated.

Reviewer 3:
Technical resources are sufficient. The reviewer commented that the team might need to add the cost estimator.

Presentation Number: bat412
Presentation Title: Novel Lithium-Iron and Aluminum Nickelate (NFA) as Advanced Cobalt-Free Cathode Materials
Principal Investigator: Ilias Belharouak (Oak Ridge National Laboratory)

Presenter

Ilias Belharouak, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

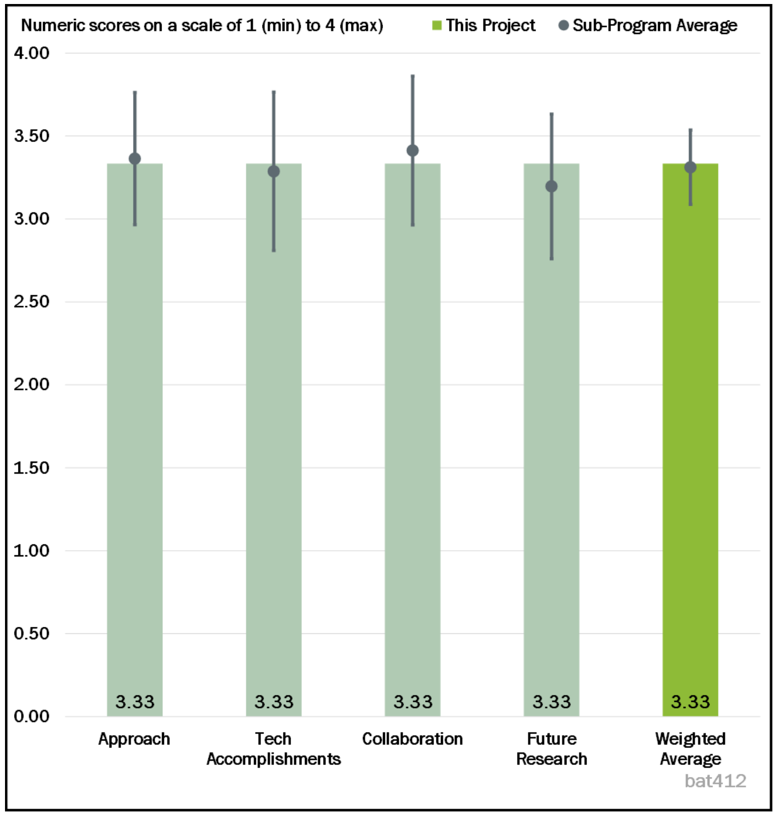

Figure 2-38 - Presentation Number: bat412 Presentation Title: Novel Lithium-Iron and Aluminum Nickelate (NFA) as Advanced Cobalt-Free Cathode Materials Principal Investigator: Ilias Belharouak (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach the team has taken to making a Co-free nickelate material has been great. The team has addressed technical barriers and overcome them. The one question from the reviewer is if the team is going to improve the electrode loading, percent active in formulation, and porosity during the electrode development.

Reviewer 2:

The work takes on the interesting task of developing and evaluating the potential of a nanostructured ferritic alloy (NFA)-based, metal-oxide cathode system. This is done in a generally credible way, the reviewer said, and that synthesis aspect of the work appears more accomplished than the performance-evaluation part of the work. To be fair, this is not a high-dollar project and comprehensive evaluation is a very costly endeavor. As with other projects in this subset, there is little benchmarking available at this stage of the work.

Reviewer 3:

Overall, this is a very well managed research project. The reviewer was curious about why Fe was used as a substitute. The amount seems to be very low and since there is no benchmarking versus commercially available materials with the same Ni+Co content, the claim that Fe improves rate capability is not supported. Provided industry “scare” of any Fe in the material, it will be interesting to know the OEM feedback. There have been many publications for the $LiNiO_2$ with Al, Mg, Ti, etc., doping. Why Fe? Is it the mentioned high sensitivity to moisture due to Ni, not Fe? Or both? Why the volumetric energy density is low? Is it due to the synthesis route?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
According to the reviewer, this is very solid, high-quality experimental work. It will be useful to add benchmarking versus industrially produced samples of similar composition.

Reviewer 2:
The team has successfully synthesized phase-pure nickelate and used advanced characterization to understand the material. The electrochemical performance was great for preliminary work. The team has also shown the ability to use a scale-up process to make kilogram-level quantities of the material with electrochemical performance comparable to a small batch. Lastly, the reviewer stated that the team has shown a technical approach to fabricating large-format cells for testing.

Reviewer 3:
The production and characterization of the material targets appears to be on track and competently done. Performance characterization needs more work, but the reviewer noted that this is also not scheduled to be completed at this time.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer asserted that there was great use of the National Laboratories and industry resources.

Reviewer 2:
The ream has used collaborations to its advantage, and it shows with the quality of work and the transfer to larger scale pouch cells.

Reviewer 3:
There was no work product from either Xalt or Nissan displayed in the presentation. It was not clear to the reviewer from the presentation when their contribution will be required and what specific tasks they will be performing.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The team has a good, proposed future-research plan and should be able to hit its targets.

Reviewer 2:
The Gen-2 NFA development culminates in a cell build and characterization effort. In order for the material to get a fair evaluation for future promise, a fair bit of planning needs to go into the structure of that evaluation.

Reviewer 3:
The reviewer suggested that benchmarking versus commercial materials tested in the same cell design should be added.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is very relevant as a Co-free cathode with higher energy density.

Reviewer 2:
The reviewer said that this is an intriguing alternative to NCA-style cathode chemistry and deserves a robust evaluation for its potential effectiveness.

Reviewer 3:
There are not enough data for the reviewer to understand the motivation for the use of Fe.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources are sufficient for the project.

Reviewer 2:
There are well coordinated and utilized resources.

Reviewer 3:
The reviewer said that resources are sufficient for now; evaluation resource sufficiency will be more on display next year.

Presentation Number: bat413
Presentation Title: High-Performance, Low-Cobalt Cathode Materials for Lithium-Ion Batteries
Principal Investigator: Donghai Wang (Penn State University)

Presenter

Donghai Wang, Penn State University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 33% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

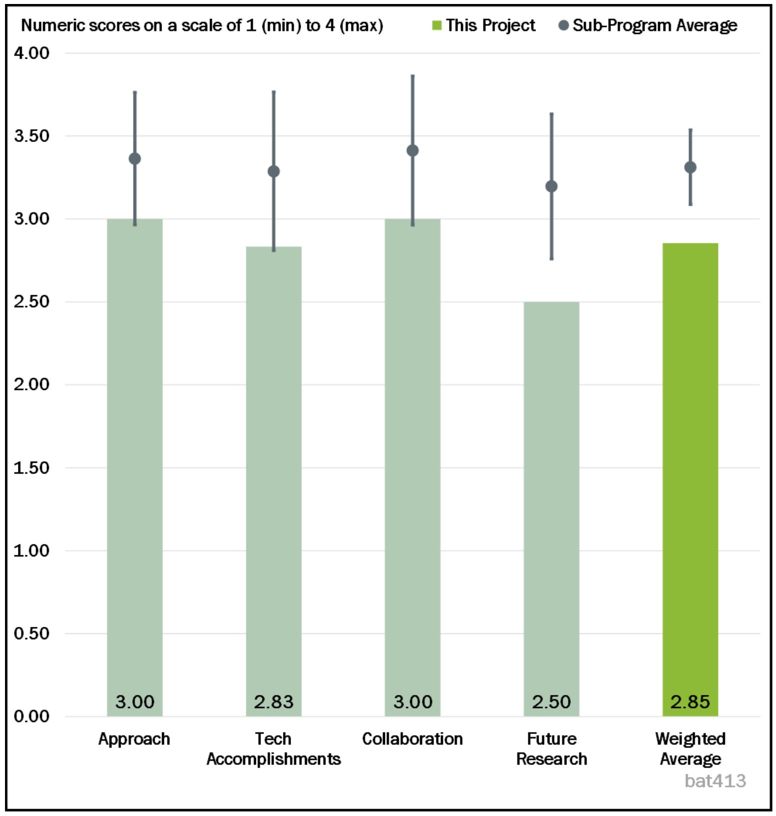

Figure 2-39 - Presentation Number: bat413 Presentation Title: High-Performance, Low-Cobalt Cathode Materials for Lithium-Ion Batteries Principal Investigator: Donghai Wang (Penn State University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer viewed the approach of producing high-Ni NCM with low-Co content through coatings and doping as solid.

Reviewer 2:

There is a mix of approaches being tested here, with varying issues associated with each one. There is some good output related to technique development in materials analysis at the atomic level, which may be the more compelling output of the program to date.

Reviewer 3:

Industry has been using low-Co, high-Ni materials for some time. The team has focused on making a number of pretty standard compositions and, hopefully, it can spend more time on establishing structure and performance relationships and use advanced characterization tools to establish new material-development principles. Since the team is having difficulties in making high-quality materials, the reviewer suggested that it might consider partnering with the teams that have high-quality samples and use them for investigations and theories development.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The team's coated aluminum oxide (Al_2O_3)-NCM performance is not good. It does not make sense that the capacity drops so much with the DC-NCM-Al_2O_3. Also, the reviewer stated that the bare NCM material is really poor, so it is a bad comparison.

Reviewer 2:
The objective of this project is to develop stabilized NCM cathode materials with low-Co content. The work done to date shows a few interesting ideas; however, it seemed to the reviewer that the team has spent most of its time on making samples versus doing a deep drive into atomic- and electronic-level correlation of the structure and chemistry.

Reviewer 3:
The reviewer found no consistent theme within the work but rather a mix of different approaches based on different material sets and development activities.

The first approach is the attempt to apply coatings as a stabilizing material for metal-oxide cathode materials. Lithium-iron phosphate (LFP) is applied to NMC811 to some positive effect. Unfortunately, NMC811 is not an acceptable candidate within the goals of the low-Co program, and the LFP coating technology is not applied to any other material. An Al_2O_3 coating is applied to a low-Co (Co=0.055) NMC material. Al_2O_3 is a common coating technology in the industry these days and is well known to provide some benefit and is widely available in commercial materials. The NMC material chosen has very poor cycle life, which is not helped by the Al_2O_3 application in this case (at least in the sense of an 80% cycle-life cutoff value)

Next, a LNMM0 material is synthesized and tested with no coatings. Cycle life is very poor, and much work would need to be done to improve it.

Finally, a NM91 material is synthesized and cycle life is essentially non-existent.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
It seemed to the reviewer like the collaborations have been used appropriately. Perhaps more input on the quality of the non-coated NCM could have been discussed further.

Reviewer 2:
The characterization performed by PNNL seems like a good contribution to the field. The split of work between Penn State and ORNL was not completely clear to the reviewer although at some point the presenter suggested that ORNL did the Mo-doped material.

Reviewer 3:
The team might consider adding a partner to accelerate sample preparation so they can have more time on characterization.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed work for the remainder for FY 2020 and for FY 2021 seemed adequate to the reviewer.

Reviewer 2:
The proposed research is mainly focused on producing pretty standard composition samples.

Reviewer 3:
The serious deficiency of cycle-life capability for many of the materials needs to be addressed at a more fundamental level before further work should be considered.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is very relevant in terms of reducing the Co content in NCM cathode materials as well as providing surface coatings to help stabilize the NCM high-Ni structure from electrolyte decomposition.

Reviewer 2:
These are legitimate materials developments to apply to low-Co. It could benefit from a more coherent approach.

Reviewer 3:
The objectives are relevant, but the reviewer was not clear if the team can meet them.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The team has sufficient resources.

Reviewer 2:
No comment was indicated by this reviewer.

Reviewer 3:
The reviewer said that the project might need help with sample delivery for studies.

Presentation Number: bat414
Presentation Title: Enhancing Oxygen Stability in Low-Cobalt, Layered-Oxide Cathode Materials
Principal Investigator: Huolin Xin (University of California at Irvine)

Presenter

Huolin Xin, University of California at Irvine

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

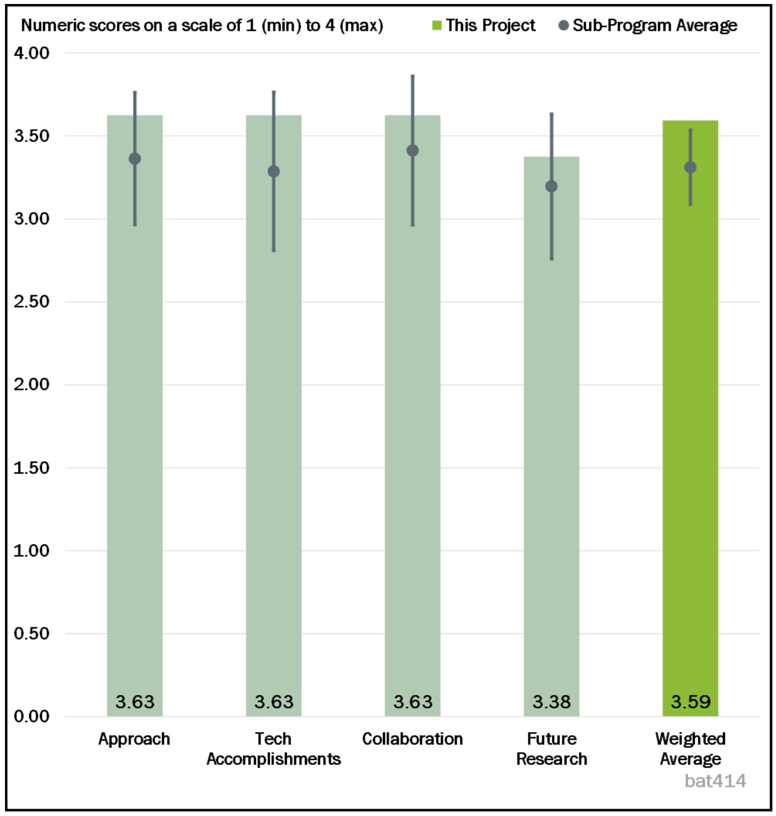

Figure 2-40 - Presentation Number: bat414 Presentation Title: Enhancing Oxygen Stability in Low-Cobalt, Layered-Oxide Cathode Materials Principal Investigator: Huolin Xin (University of California at Irvine)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach is systematic, and the strategy covers the path to test several hypotheses to meet the project objectives. According to the reviewer, there is an excellent balance of theoretical and laboratory work. There is excellent marketing: the work on surface and bulk doping of $LiNiO_2$ with Ti and Mg had been published in 1998 but using the term 3-D doping technology should re-invigorate the interest and use by industry, provided that IP will expire this year. This reviewer also recommended *Electrochemical and Solid-State Letters* 1 (3) 117-119 (1998): Novel $LiNiTiMgO_2$ Compounds as Cathode Materials for Safer Lithium-Ion Batteries.

Reviewer 2:

The approach is great to investigate lowering the Co amount in high-Ni NCM materials through surface and bulk doping. The team also utilizes modeling to understand the role of the improvements of dopants.

Reviewer 3:

The PI proposed highly effective approaches to address the barriers. In addition to novel electrolytes and cathode doping, the PI also proposed high-throughput computation to guide materials design. The PI recognized the critical issue of O loss in high-Ni NMC and proposed techniques to characterize and mitigate O loss.

Reviewer 4:

The work is intending to apply a scientific approach to doping high-Ni metal-oxide cathode materials in order to replace the function of the Co. The reviewer reported that the project has a good blend of experimental and theoretical approaches that should help better understand the concept and potential efficacy. There is some interesting electrolyte interaction work that is also applied although there is less analysis applied to the fundamental mechanistic improvements that the electrode-electrolyte interface is exhibiting.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer asserted that there was impressive computational work for dopants selection and an excellent demonstration of the electrolyte formulations on SEI-CEI stability.

Reviewer 2:
The project's technical accomplishments are great. The team has doped NMC811 and used advanced analytical characterization to understand the role of the dopant as well as using computational modeling. From that, the team has been able to do co-doping to further improve performance. Additionally, the team has found electrolytes that will work with the team's full-cell system that show superior performance to the baseline.

It would be good, however, to show the stability in various storage applications for the NMC material. High-Ni NCM tends not to be stable when stored in humidity or air for long periods of time. It would be interesting to the reviewer to see how the material performs with storage testing, as well as looking at the amount of residual lithium hydroxide and lithium carbonate on the surface as a function of storage time and relative humidity. It would be interesting to see if the surface coatings help with this.

Reviewer 3:
Based on modeling guidance, the team synthesized surface and bulk-doped, Co-free nickelates and demonstrated good cycle life in the doped nickelates. The team also demonstrated the effectiveness of an LHCE in reducing the cycle-life fade of Co-free nickelates.

Reviewer 4:
The impact of the doping on basic performance and the fundamental analysis elucidating some aspects of the mechanism from a materials point of view is fairly strong. There is good analysis followed by relevant conclusions.

Again, the electrolyte interaction work was interesting, but with a less fundamental mechanistic conclusion.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The team has used its collaborations to its advantage. The work done is great and seems that all parts are working together.

Reviewer 2:
The PI assembled an excellent team, with clear description of the role of each team member.

Reviewer 3:
The reviewer commented that there is outstanding use of the talent, characterization tools, and theory within the National Laboratory network.

Reviewer 4:
There is good interaction between synthesis, modeling, analytical analysis and interpretation—good job.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The team discussed the remaining challenges of thermal stability and scale-up and should also consider storage life of the NCM powder. Otherwise, the proposed future research plan is good.

Reviewer 2:
The path forward is clear, and the choice of NMC622 for benchmarking is a good target.

Reviewer 3:
Hopefully, the scale-up work to 100-g level is sufficient to support the next level of characterization. The reviewer asked if that level may be a little light.

Reviewer 4:
Even though the project is only 40% completed, the reviewer commented that great progress was made in demonstrating the feasibility of Co-free nickelates. Due to the high 4.4 V cut-off, in addition to cycle life, the team needs to demonstrate progress toward achieving the stated 15-year calendar-life goal in fully charged cells. The team should also demonstrate performance using cathode loadings of 3-4 mAh/cm^2 in order to meet the energy-density targets.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The work will provide a knowledge base for selection of the dopants and further emphasize the role of the electrolyte formulation.

Reviewer 2:
The work on lowering the Co amount and having high-energy cathode materials is relevant, according to the reviewer.

Reviewer 3:
In the realm of stabilizing high-Ni materials without the use of Co, this is an obviously a good set of approaches to develop options based on understanding.

Reviewer 4:
The project is very relevant for a program on low-Co cathodes. The PI should elaborate on the uniqueness of the doped nickelates by taking into consideration the Co-free nickelates effort published by Dahn's group—*JES* 166(4), A429 (2019). While the PI demonstrated feasibility of $LiNiO_2$ doped with Mg and Mn, the absence of Mn in Dahn's $LiNi_{0.95}Mg_{0.05}O_2$ might reduce the TM- dissolution issue.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The right talent and tools are in place.

Reviewer 2:
All the proper bases appear covered.

Reviewer 3:
The reviewer said that the team has sufficient resources to solve its challenges.

Reviewer 4:
The project has sufficient resources.

Presentation Number: bat415
Presentation Title: High-Nickel Cathode Materials for High-Energy, Long-Life, Low-Cost Lithium-Ion Batteries
Principal Investigator: Arumugam Manthiram (University of Texas at Austin)

Presenter

Arumugam Manthiram, University of Texas at Austin

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

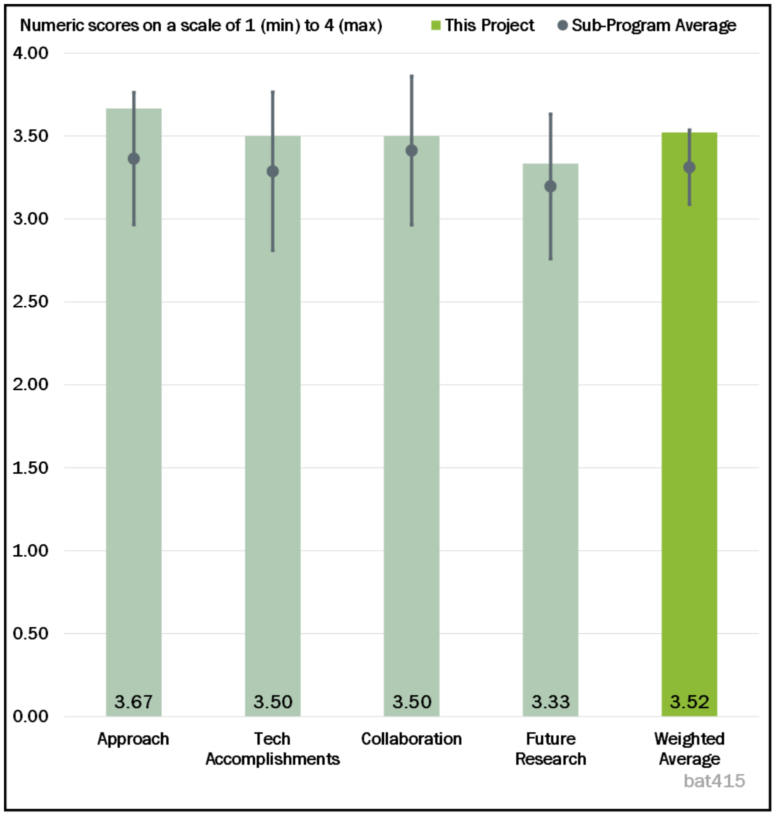

Figure 2-41 - Presentation Number: bat415 Presentation Title: High-Nickel Cathode Materials for High-Energy, Long-Life, Low-Cost Lithium-Ion Batteries Principal Investigator: Arumugam Manthiram (University of Texas at Austin)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The work on low Co and the approach presented by this group is great. It has a focused goal to investigate the compositions and scale-up of the material.

Reviewer 2:

The reviewer found this to be a very well designed and executed experimental plan. The team might benefit from the work conducted under BAT414 in regard to the guidance and strategy for the selection of the dopants using the modeling tools. There is excellent work for the technology assessment using commercially relevant requirements.

Reviewer 3:

This work explores the familiar theme of minimizing Co in Ni-based cathode materials by trying to substitute other stabilizing structural and dopant components. It contains good experimental and analytical evaluation.

Interaction with collaborators does not seem very coordinated, and the reviewer asserted that some attention should be paid to following up on the good results that are currently being generated.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The technical accomplishments are excellent, and they show the need for an O_2 atmosphere for annealing these high-Ni systems. According to the reviewer, the doping also shows improvements over the pure $LiNiO_2$. The team was also able to show high cycling stability with 2 Ah pouch cells.

Reviewer 2:
Very high-quality work and steady process were observed by this reviewer.

Reviewer 3:
Several base-material combinations have been tested and evaluated. The nickel manganese aluminum (NMA) material exhibited good behavior versus some reasonably well-known standard materials. The effect of calcination pressure was also an intriguing study that seemed to show a strong response.

The initial doping studies are interesting; however, with a comparison only to the control—pure NiO_2 material—it is a little difficult to assess just how the doped materials compare to known standard material sets.

Work performed by partner NREL provided a LiNiCoMnAlMg material to Tesla for evaluation. It was not clear to the reviewer why this material was chosen or how it fits into the overall program.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer called this a great team and gave kudos for having an OEM on board to provide assessment and feedback.

Reviewer 2:
The team displays a great use of collaboration.

Reviewer 3:
The collaboration between UT-Austin and NREL does not seem to be particularly well coordinated. The roles and synergies between the two organizations was not very evident to the reviewer from this presentation.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The team's approach to attempting higher electrode loading and studying the calendar effects are industry relevant and important for the success of this material.

Reviewer 2:
The stated goal for the future is a survey of LiNiCoM material with dopants as well as ALD coatings, followed by evaluation of Co-free versions of the same. The reviewer was not sure why the Co-containing versions are receiving attention, given the work already done in the NMA Co-free version. Hopefully, the work on Mg-Cu doping that was performed will also be followed up on.

Reviewer 3:
The team might consider reviewing the models developed within the DOE program (for example, BAT414) to guide selection of the dopants; the reviewer opined that this might accelerate discovery and objectives delivery.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is very relevant for removing Co from cathodes while having high capacity and cycling performance.

Reviewer 2:
This team is one of the most knowledgeable in the high-Ni research field and has the most experienced partner to do evaluation and testing.

Reviewer 3:
Stabilization of NiO_2 -based cathode materials with materials other than Co, as well as dopant and coating approaches, is the most likely path toward a Co-free, high-energy cathode system.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The team has displayed that it has enough resources for the success of this project.

Reviewer 2:
The reviewer had no issues.

Reviewer 3:
Using recent modeling developments within the DOE program might accelerate this team reaching their milestones for the survey of the compositions and dopants.

Presentation Number: bat416
Presentation Title: Cobalt-Free Cathode Materials and Their Novel Architectures
Principal Investigator: Shirley Meng (University of California at San Diego)

Presenter

Shirley Meng, University of California at San Diego

Reviewer Sample Size

A total of # reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

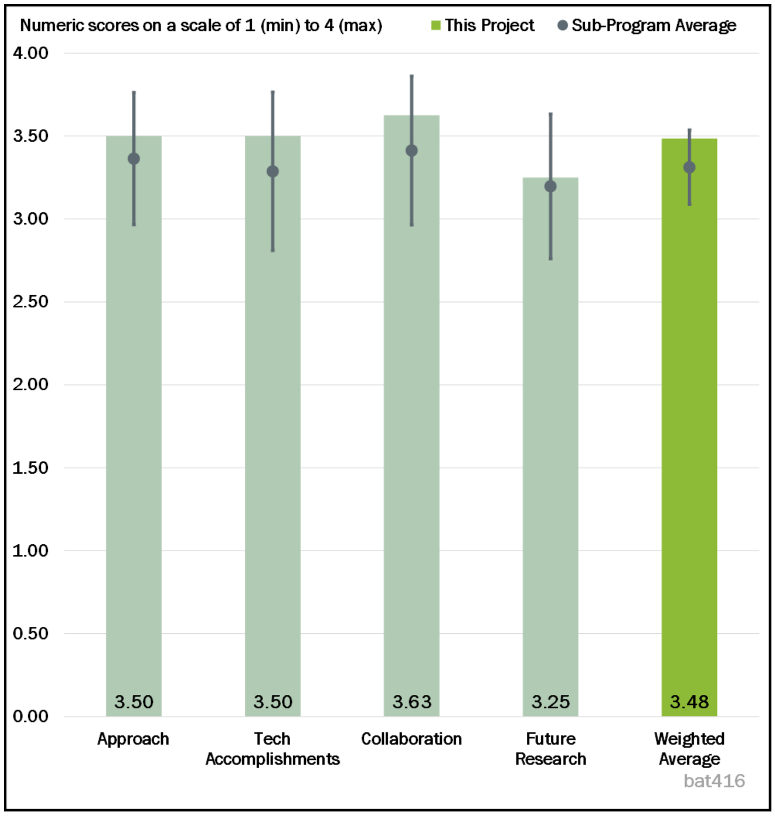

Figure 2-42 - Presentation Number: bat416 Presentation Title: Cobalt-Free Cathode Materials and Their Novel Architectures Principal Investigator: Shirley Meng (University of California at San Diego)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer asserted that this was a very thoughtful and practical approach to mitigate the limitations preventing use of the LMNO chemistry. The attention to details and the development of the new characterization techniques are commendable. The reviewer was curious about what the partners think about the high-voltage requirement to reach energy-density targets and what the plans are to solve performance issues at elevated temperatures. It will also be interesting to see if the dry-electrode method will work for other cathode chemistries.

Reviewer 2:

The reviewer indicated that the approach of Co-free $LiNi_{0.5}Mn_{0.5}O_2$ (LNMO) with thick electrodes is great. The team has the necessary experience and has addressed the technical barriers. The project is well designed and feasible.

Reviewer 3:

The approach in this effort is through the use of reasonably well known LNMO material but with a high tap density and thick electrode structure to make up for the inherent lower capacity of the LNMO material. This is probably worth exploring in order to cover all possibilities in the search for an acceptable low-Co material.

Reviewer 4:

The PI proposed effective approaches to address the barriers. A combination of surface characterization tools was used to understand the electrode-electrolyte interface instabilities. Novel electrolyte additives and cathode doping were proposed to address the high-voltage electrolyte instability, and a dry cathode coating was proposed to fabricate thick electrodes.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer remarked that this is high-quality research: attention to details leads to better material and cell designs. The research is on track.

Reviewer 2:
The technical accomplishments are great. The team studied the binder and conductive carbons, which are an important aspect when dealing with high-loading electrodes. Additionally, stack pressure is important as the team shows. The technical challenges that remain are to address the rate performance with these high-loading electrodes.

Reviewer 3:
The reviewer commented that the accomplishments to date mainly center around base-material identification and electrode- and cell-architecture baselines.

Reviewer 4:
The team was successful in increasing the loading and demonstrating cycle-life feasibility with 3 mAh/cm^2 in pouch cells. TM dissolution from the cathode deposited on the anode and Li-inventory loss were identified as major contributors to cycle-life fade.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that the PI assembled a team of experts, including an industry partner that contributed to the success to date.

Reviewer 2:
There is the right talent on the team to solve the limitations of the LMNO chemistry.

Reviewer 3:
The team has used its collaborations adequately.

Reviewer 4:
Due to the baseline process and design work, there has not been a lot of opportunity to view collaboration dynamics. This will be more relevant in future work.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer noted that the team will aim to dry coat the LNMO to make single-layer pouch cells, which is important, as well as study the effect of electrolyte and electrolyte additives.

Reviewer 2:
The project is 50% completed. Building on the success of the first half, the team needs to demonstrate the effectiveness of its approaches in mitigating high-voltage electrolyte instabilities. Due to the ultra-high voltage cathode, in addition to cycle life, the team also needs to demonstrate stable calendar life in fully charged cells. Since stack pressure is critical to good cycle life, the pressure impact should be quantified.

Reviewer 3:
Future research is predominantly focused on characterization of the modified LMNO samples with different electrolytes and electrodes made using dry coating method. It will be beneficial to assess the cost, safety, and performance implication of the high-voltage requirement on the battery-pack design and seek feedback from the OEM partner. In addition, there is a need to focus on the elevated temperature performance.

Reviewer 4:
The specifics of the material-modification approaches for the LNMO material are not well defined in the presentation, according to the reviewer.

Electrolyte studies related to reactions at the electrode-electrolyte interface should be of some interest as this is a higher voltage system that may have complications in this area.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The use of the dry-electrode production method is very important from the viewpoint of cost and environmental impact to the industry. The reviewer indicated that the ability to increase areal electrode loading with no detriment to the rate capability is another strength of this project.

Reviewer 2:
LNMO cathodes with high loading are important for industry.

Reviewer 3:
LNMO is a Co-free material with a commercial history in the Li-ion industry. Exploring its limits seems like a reasonable goal for a zero Co-cathode system.

Reviewer 4:
The reviewer stated that the research is relevant for a project on low-Co cathodes. However, a comparison of cost, energy density, and life based on full cells should be made with low-Co or Co-free NMC to justify the risks associated with the ultra-high voltage LNMO spinel.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The right balance and good long-term relationships are in place.

Reviewer 2:
The reviewer stated that the team has sufficient resources for this project.

Reviewer 3:
The reviewer had no issues.

Reviewer 4:
Since the electrolyte is a critical enabler for the ultra-high voltage LNMO, some resources should be devoted to electrolyte development.

Presentation Number: bat417
Presentation Title: Cobalt-Free Cathodes for Next-Generation Lithium-Ion Batteries
Principal Investigator: Neil Kidner (Nexceris)

Presenter

Neil Kidner, Nexceris

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 33% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

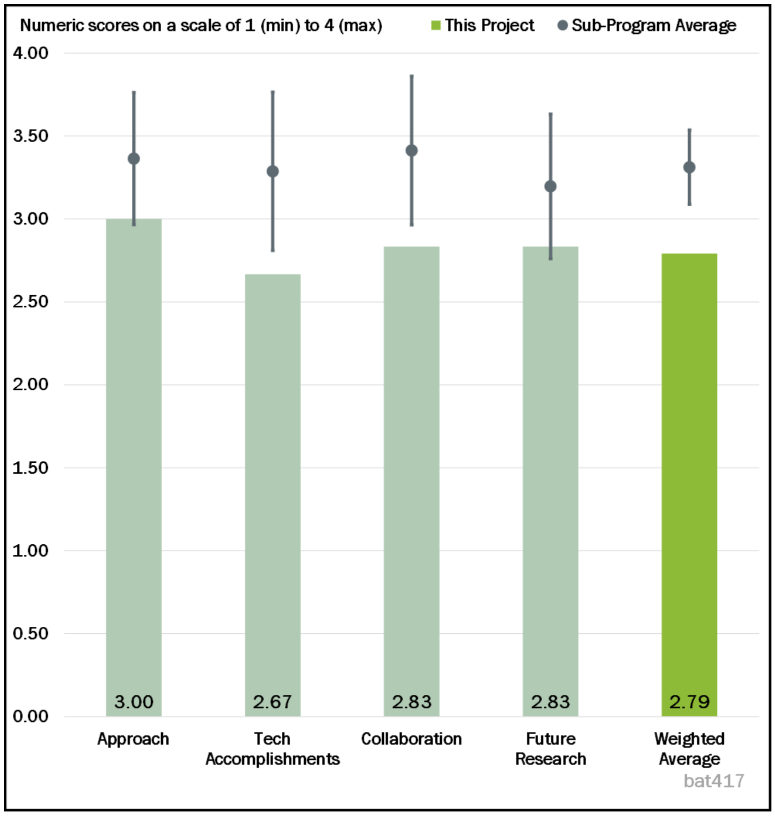

Figure 2-43 - - Presentation Number: bat417 Presentation Title: Cobalt-Free Cathodes for Next-Generation Lithium-Ion Batteries Principal Investigator: Neil Kidner (Nexceris)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach consists of providing a Ti-rich, core-shell layer on the surface of LNMO cathode material. Integrated shell layers are a well-known approach and the value of this specifically is certainly worth addressing.

Reviewer 2:

The plan is to make LNMTO cathodes with improved cycle and calendar life by forming an SEI through a core-shell approach. While the approach in theory is good, it was unclear to the reviewer if the direction the group is taking is the best. For example, in the coin-cell work, the team used a PVDF binder, but showed lithium polyacrylate (LiPAA) in the full cells. It seemed to the reviewer that PVDF cycles were much better than the LiPAA cycles, so it was unclear why there was a change. The team also does not adequately show why it is using Ti in the LNMTO system. It seems like the team needs to regroup on its approach to better address the technical barriers.

Reviewer 3:

The initial results show that LMNTO cathode capacity is decreased while the cyclability is not improved to meet the project targets. It was interesting to the reviewer to see that LMNO used for comparison fades too rapidly. In the BAT416 presentation, researchers demonstrated more than 300 cycles at 80% capacity retention. Therefore, it is difficult to understand the motivation for continuation of the investigation of this cathode chemistry, which is further complicated with the high-voltage-performance requirement not yet embraced by the OEMs. It was obvious to the reviewer that the co-precipitated syntheses method will result in higher uniformity, but as researchers indicate, it will be difficult to scale up. Researchers might need to review their strategy to ensure project objectives are met.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented that the initial results are far from reaching the project objectives on all merits except that the material is Co free.

Reviewer 2:
At one level, the results show that the addition of a shell layer of Ti-rich material provides a marked improvement over the non-coated material. The reviewer's concern with these results is that the performance of the LNMO control material is very poor. The LMNTO material does provide favorable improvement but also poor performance on an absolute basis. There needs to be some concern about the poor performance of the control material before too many conclusions are drawn.

Reviewer 3:
The scale-up from 20 g to 2 kg shows a drop in capacity as well as differences in the voltage profile. It was unclear to the reviewer why that is the case, but it may be due to homogeneity in the synthesized particles. It would be good to have confirmation through inductively coupled plasma that the team is also getting the desired stoichiometry. The work shown in the 2-Ah pouch cell shows improvement but with a really poor baseline. Unfortunately, the group presenting before them showed 3.5-Ah cycling in a pouch cell for LNMO baseline, and that had much better performance. It is also unclear how much a of cost difference there is between the solid-state versus co-precipitation methods shown.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration seemed appropriate to the reviewer. Synthesis, lab-cell analysis, and larger pouch-cell builds appear to be in place.

Reviewer 2:
Navitas is a very experienced team and might need to be more engaged to provide direction.

Reviewer 3:
It indicated to the reviewer that the team could have used its collaborations better to achieve their project goals: for example, the changing of binders, the scale-up that does not show the same cycling performance, and the 2-Ah cells that do not reach the desired cycle life.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer suggested that re-evaluating the strategy should be the number 1 priority.

Reviewer 2:
The reviewer asserted that the team should go back and address some of the other issues brought up in terms of electrode formulation (i.e., binder, carbon, and loading) before moving to the proposed future work.

Reviewer 3:
It is stated that a large amount of the performance shortfall of the material is related to the electrolyte-degradation issue in the high-voltage environment. An electrolyte study is prudent; however, this is a challenging task and requires specific expertise that is not necessarily accounted for in the collaboration.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
LNMO is a well-known chemistry in the field with well-known pros and cons. If there are material developments that could improve upon the system, they would serve the goal of finding high-energy material without a significant Co penalty.

Reviewer 2:
The reviewer stated that the project is relevant research but needs better focus and the ability to hit the targets.

Reviewer 3:
The reviewer asserted that there is a need to have help and/or direction.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
It seemed to the reviewer that the team has sufficient resources.

Reviewer 2:
Resources are sufficient unless the focus on electrolyte needs to be acted upon within this effort.

Reviewer 3:
The team needs additional collaborations and to re-evaluate its strategy, according to the reviewer.

Presentation Number: bat436
Presentation Title: Silicon Electrolyte Interface Stabilization (SEISTA): Update and Overview
Principal Investigator: Tony Burrell (National Renewable Energy Laboratory)

Presenter

Tony Burrell, National Renewable Energy Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

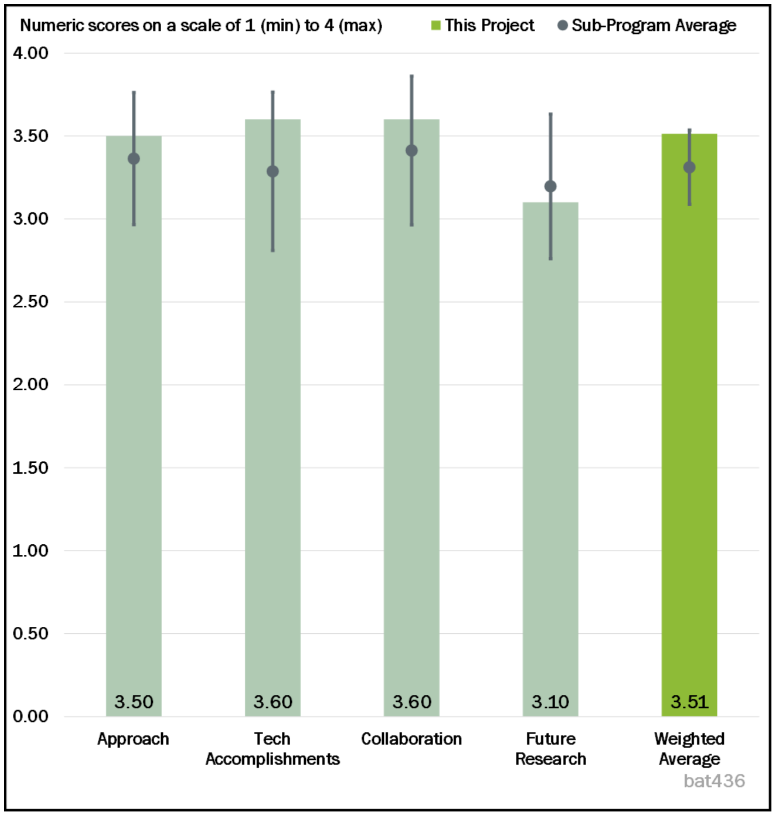

Figure 2-44 - Presentation Number: bat436 Presentation Title: Silicon Electrolyte Interface Stabilization (SEISTA): Update and Overview Principal Investigator: Tony Burrell (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project is well organized, well designed, and highly focused. It was very evident to the reviewer that a lot of careful thought had gone into planning this project.

Reviewer 2:

The overview to the Silicon Electrolyte Interphase program did a good job of addressing the important technical barriers and does a good job coordinating the large number of researchers working on the project. The goals of the project were clear to the reviewer, and the design of the work groups and the work packages is good. The project has feasible goals that will likely provide benefits to the U.S. automotive industry by laying the groundwork to improve the energy density of anodes for LIBs.

Reviewer 3:

The reviewer listed some comments:

- It is a careful approach.
- Calendar life is called out, but there is no follow-up.
- Looking for alloys that enhance durability is a very important approach.
- Rather than just characterizing everything, a particular Zintl phase is identified as important and useful, so the work focused there.

Reviewer 4:
This project appears to be well designed and has significant communication with adjacent energy-storage programs, including the Deep Dive, in order to ensure that there is not a duplication of work. The presenter mentioned that the team is stage-gating sub-programs with go/no go decisions in order to ensure it is continually focusing on promising projects.

The presenter described a critical step in the validity of this project by standardizing the testing protocols between groups to predict calendar-life testing. This enables much for more reliable testing between laboratories in the consortium.

Reviewer 5:
This was a good overview of a lot of work. However, the reviewer indicated like it did not tie together as well as last year. A strength is that the group is seeking to understand what is critical to fixing the problem, and this is the group that can do it. A weakness is the focus on areas that are not necessarily mainstream to get the understanding.

Is Mg the answer? There is a lot of effort on this, but will the understanding really help? The reviewer sees that the industry is moving toward SiO_x, and asked where that understanding is? The reviewer knew that the team needs to focus narrowly to get understanding, but is the narrow focus aligned with where the industry is?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The technical accomplishments of the Silicon Electrolyte Interface Stability (SEISTA) program have been impressive. The project has focused on the systematic investigation of uniform model-Si samples. The reviewer asserted that this is a wise methodology since differences in Si frequently cause large changes in performance. The team has also utilized a wide array of novel analytical methods to investigate the materials. These novel methods have provided significant new insight into the surface reactivity and SEI stability of Si anodes.

Reviewer 2:
The project has made significant contributions toward fundamental understanding of Si-anode properties using a variety of SOA analytical techniques. This has been the salient feature of these investigations and kudos to the teams for doing an excellent job in achieving this objective.

The reviewer was kind of hoping that this high-powered talented team with significant resources and time will be coming up with a solution for the Si anode that will be ready for use in a long-life cell. However, based on the current data, it was not clear to the reviewer that the teams were able to achieve that goal.

Reviewer 3:
The presenter described a high-level overview of all projects occurring via the SEISTA program. Significant breakthroughs may have been achieved with regards to the Mg-salt addition to form the in situ Zintl phase. This project seems to have good results and has been a cross-cutting project between various subtasks.

Interesting differences between the model system and the particles were mentioned—with different mechanisms for the thin-film applied Mg-Si system compared to the electrolyte—and will need to be investigated. Various other projects were mentioned with limited success, such as forming Si-Ni and Si-Sn alloy materials.

Discussion of a new, bulk-metallic-glass, synthesis process via “splat quenching” was described although it was not clear to the reviewer how it differed from previous synthesis methods pioneered by 3M for induction melting and rapid quenching.

Reviewer 4:
The reviewer listed the following comments:

- "Lifetimes of full cells can be predicted using AIC (accumulated irreversible capacity) values determined from short half-cell experiments." Numerous studies have shown that there is often a knee in the capacity fade that may not show up for hundreds of cycles.
- Use of thin film samples with Mg is a great idea.
- Considering life history is a good idea, but there is no follow-up.
- Pathways are proposed for how these experiments can lead to improved batteries; for example, stabilizing Li silicide with the Zintl phase.
- Metallic glasses show promise for lowered SEI.
- Where is work on calendar life?

Reviewer 5:
Each project has good technical accomplishments: a lot of effort and good characterization. The reviewer would like to have seen more links between projects for general conclusions though.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There are fantastic collaborations among team members, according to the reviewer.

Reviewer 2:
This is an overview of a large team project. The team clearly interacts regularly and utilizes the resources of different National Laboratories effectively. The projects leaders do a good job of coordination of the many different projects. Since the performance of Si anodes is dependent upon many different factors, a large team approach with many different researchers studying the same materials is very important for the development of a consistent understanding of these complicated materials.

Reviewer 3:
The reviewer stated that this is a well-coordinated team project that really leveraged the excellence of each laboratory.

Reviewer 4:
The projects appear to have clear alignment and collaboration between institutions.

Reviewer 5:
The reviewer said that it is good the team meets and is aware of the other projects within the broader effort. The rigorous sample and experimental control are great. Broader questions and hypotheses need to be stated more clearly, with an effort across projects to address common hypotheses.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The future research proposed by the SEISTA team appropriately addresses many of the remaining issues with Si anodes. The development of systematic testing protocols will be needed to understand the subtle differences in these systems. It was clear to the reviewer that developing a strong understanding of the SEI stability and mechanical properties will be needed to design superior interfaces. Some alloy and surface-modified data are

very promising, and the expansion of these efforts is merited. These proposed areas will likely lead to improved Si electrode systems for electric vehicle applications.

Reviewer 2:
The reviewer's reservation was whether the proposed work will lead to a commercially viable solution and be competitive with SOA Si technologies.

Reviewer 3:
This reviewer referenced the presentation—"Identify solutions to SEI stability based upon SEISTA understanding and direct"—and noted that this does not sound like there are any specific ideas for how to accomplish this.

Reviewer 4:
The presenter describes proposed future work from a very high level but did not describe actionable pathways or new projects that the team will undertake to address existing barriers. Significant gaps between the SEISTA program and commercial interests (5-10-year horizon) remain; the reviewer hopes that learnings from the SEISTA program will eventually be applicable to real-world scenarios.

Reviewer 5:
The future work listed on the slides is certainly necessary, but not specific enough. The reviewer agreed with the bullet—"Understanding the mechanical features of the SEI will be important."—and asked how. Which project will focus on that?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
According to the reviewer, this project supports the DOE objectives of developing lower cost, higher energy density LIBs for electric vehicles. The development of improved Si or Si-graphite composite anodes is one of the few viable methods to increase the energy density of the anode for LIBs. This team is addressing the important problems in an appropriate manner.

Reviewer 2:
The reviewer stated that Si is critical to the DOE roadmap. In spite of massive amounts of work by both industry and academia, problems are still not solved. We need the advanced characterization techniques being developed within this program to understand and solve the issues.

Reviewer 3:
LIB technology is a critical national security issue and one of the keys to achieving U.S. energy independence. It is well understood that Si-anode technology is vital to decreasing the costs of LIBs to threshold levels required to compete with IC engines for electric vehicles. The SEISTA program aims to address some of the shortcomings of Si technology in order to accelerate Si adoption, thereby leading to reduced battery costs and improved transition to electric vehicles. The reviewer commented that the exact projects researched under SEISTA in order to accelerate commercial Si adoption can be debated.

Reviewer 4:
This project is very relevant to overall DOE overall objectives.

Reviewer 5:
Calendar life, which is widely ignored, is explicitly examined here.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources and the time provided for this project were significant and sufficient.

Reviewer 2:
Resources seemed sufficient to the reviewer and appropriate for this large, multi-organization project spanning five National Laboratories and many universities.

Reviewer 3:
The project is appropriately resourced.

Reviewer 4:
Resources are sufficient.

Reviewer 5:
The reviewer did not think it is possible to fully understand Si anodes in 2020. The milestones are quite specific, so doable. There are a lot of people working on this.

Presentation Number: bat437
Presentation Title: Silicon Electrolyte Interface Stabilization (SEISTA): Electrochemical Methods
Principal Investigator: Robert Kostecki (Lawrence Berkeley National Laboratory)

Presenter

Robert Kostecki, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

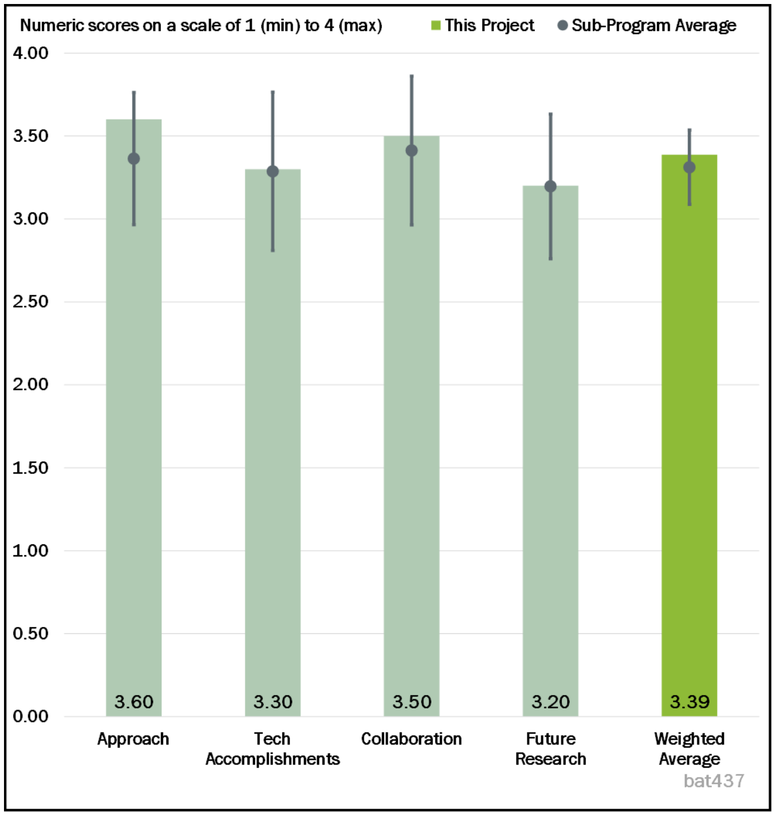

Figure 2-45 - Presentation Number: bat437 Presentation Title: Silicon Electrolyte Interface Stabilization (SEISTA): Electrochemical Methods Principal Investigator: Robert Kostecki (Lawrence Berkeley National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach to investigating the SEI on Si anodes is excellent. The three main areas investigated are the most important topics for the further development of Si anodes for LIBs. The investigation of electrolyte modifications is an important area of focus. The investigation of CO_2 as an electrolyte additive is important, and the additional information obtained by this project is very useful to the battery community. The modification of the Si surface via Zintl-phase formation is both interesting and provides a platform for additional investigations. Finally, the approach of investigating alloys may lead to the development of additional novel materials.

Reviewer 2:

According to the reviewer, this project is well designed and hits at the core of the issue. The reviewer commented that Si stability and performance are heavy dictated by the surface of the material, and this project focuses closely on characterization of the surface of the materials.

Projects that were grouped into three strategies were undertaken to investigate Si-electrolyte interface. Although the three overall strategies to stabilize the Si-electrolyte interface are appropriate and cover the critical research topics for the SEI (active material *S*olid, *E*lectrolyte modifications, and *I*nterface modifications), it was not clear to the reviewer how the sub-projects to prove out the three strategies were decided and/or why they are the most promising paths to research.

Reviewer 3:

The work was very focused and well designed to characterize and understand the Si-anode properties.

Reviewer 4:

Slide 4 is excellent as it clearly highlights the important questions to be answered. There is one missing, though: how broad are the answers for different types of Si? But the reviewer appreciated the thoughtful approach to this work.

Reviewer 5:

The reviewer asked the team to please explain explicitly how these experiments can lead to an improved Si anode. That is, how does knowing details of SEI help in being able to get a better SEI? Additionally, the reviewer reported three approaches suggested to improve battery performance

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The PI carried out high-quality work to characterize the Si surface properties, especially the quantitative studies. This work clearly adds to our improved understanding of this electrode and how to manipulate it for practical use. This is also true for the new materials that were investigated in this project.

Reviewer 2:

The technical accomplishments directed toward electrochemical methods for investigating the SEI on Si are impressive. All three areas of focused study provided a stronger mechanistic understanding of the system of materials with significantly improved performance. The investigations of CO_2 as an electrolyte additive did not results in significant changes to the performance of the Si electrodes. However, changes to the composition and structure of the SEI were observed and a better understanding of the structure-function relationship of the SEI was established. The accomplishments related to the generation of a Zintl phase on the surface of the Si is promising. The reduction in residual current and the improved capacity retention are both promising. The development of novel Si alloys also provides promising results toward the use of Si-based materials in LIBs for electric vehicle applications.

Reviewer 3:

The technical development to answer questions is very well done. However, the reviewer thought that the specific systems studied are not necessarily going to answer all the questions on Slide 4. The focus on Zintl compounds and CO_2 may be too specific to academia. Is the industry considering either one? Maybe focus more on binder interactions—with more than LiPAA (which is not the most commonly used binder for Si in industry).

Reviewer 4:

The presenter described accomplishments for the three strategies that were undertaken. Unfortunately, the technical accomplishments did not pan out for the electrolyte project (CO_2 gas addition). Interface modification via introduction of Mg salt was also covered in other presentations. Electrochemical and NMR results shown in this presentation suggest promising results regarding Mg-Si bond strength although more data could have been presented. The amorphous Si-alloy material synthesis and testing results were similarly short and did not appear to show significant progress. Only first two cycles were reported, with no additional cycling. Also, it was not clear to the reviewer how the alloy improved the “mechanical stability” as mentioned on Slide 19; there did not appear to be data to support this conclusion.

Reviewer 5:

Correlating thin-film Si corrosion current with full cells is very important. Yi Cui’s (*Nature Nano* 2012) hollow Si nanowires and Shaojun Guo’s nanoparticles (J. Mater. *Chem. A*, 2018, 6, 8039) were coated with

SiO_x, and they got an extremely stable SEI on the SiO_x. But this project does not get stable SEI on SiO_x. Any thoughts?

It is not clear how NMR clarifies how the Zintl phase is formed on Si anodes. Any insights into how the Zintl phase stabilizes the interface? The reviewer also asserted that understanding why Si is different from graphite is very important. When the lithium ethylene decarbonate (LiEDC) disappears upon delithiation, does the team get the Li back? If so, it does not affect the CE.

Mn has a (bad) effect on SEI if it is present in the electrolyte (from dissolution of cathode). It does not need to be incorporated into the anode to have its effect. Possibly, Mg also does not need to be incorporated into the Si to have its effect; maybe its benefits can show up simply by being added to the electrolyte?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This project benefited from excellent collaboration among the various teams.

Reviewer 2:
The reviewer stated that there was extensive collaboration, including round-robin testing.

Reviewer 3:
There appears to be significant collaboration between the teams. This is also evidenced by the similar results shown from many participating organizations for the projects.

Reviewer 4:
This project is a collaboration of many different researchers and utilizes the resources of the National Laboratories well. Much of the progress clearly involves research requiring teams of different researchers. The coordination of the different projects is strong.

Reviewer 5:
The reviewer found clear synergies between this project and others presented today. There are no issues with collaboration among the groups.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
According to the reviewer, the proposed future topics are of significant importance to the development of superior LIBs. The plan to utilize a round-robin approach for investigating the physiochemical properties is likely to lead to an improved understanding of the mechanism of SEI operation and function. This will also lead to a better correlation of interfacial properties with electrochemical performance. These fundamental investigations will provide the groundwork for the rational design of superior Si electrodes.

Reviewer 2:
There are interesting approaches that are relatively specific about just what next steps are called for.

Reviewer 3:
Item II on Slide 21 is the most important next step. There are good observations using analytical techniques, but are those observations relevant to solve the performance problems in a cell? The PI should make sure the round-robin electrodes in item I are industrially relevant.

Reviewer 4:
While the work is of very high quality, the reviewer was not sure the future research proposed will be able to reach overall DOE goal set out for this project

Reviewer 5:
The proposed future work is high level but lacks details on the direction in which the team will head. It is directionally correct but has no mention of risk mitigation, alternative development pathways, or decision points.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Battery technology is a critical national security issue and key to achieving U.S. energy independence. The reviewer remarked that Si-anode technology is required to achieve LIB cost thresholds for electric vehicles to compete with IC engines. SEISTA and this project aim to address shortcomings with Si technology, thereby accelerating Si adoption and leading to reduced battery costs and improved U.S. global competitiveness.

Reviewer 2:
This project supports the DOE objectives of developing lower cost, higher energy density LIBs for electric vehicles. The development of improved Si or Si-graphite composite anodes is one of the few viable methods to increase the energy density of the anode for LIBs. This team is addressing the important problems in an appropriate manner.

Reviewer 3:
This project supports overall DOE objectives since the improved Si anode will lead to a significantly higher energy density cell.

Reviewer 4:
The reviewer indicated that Si is an important component to address energy-density targets for the DOE roadmap. A lot of work has been done in it (industry and academia), but we are still not there. This work needs to be completed and linked to commercially relevant materials and approaches.

Reviewer 5:
The project is relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources seem sufficient and appropriate for this large multi-organization project spanning six National Laboratories and many universities.

Reviewer 2:
The resources allocated to this project are sufficient to complete this project in a timely manner.

Reviewer 3:
The project is sufficiently resourced.

Reviewer 4:
The reviewer asserted that this is a huge team and a big project. The project will not gain much by adding even more.

Reviewer 5:
Resources are sufficient.

Presentation Number: bat438
Presentation Title: Silicon Electrolyte Interface Stabilization (SEISTA): Advanced Characterization
Principal Investigator: Glen Teeter (National Renewable Energy Laboratory)

Presenter

Glen Teeter, National Renewable Energy Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

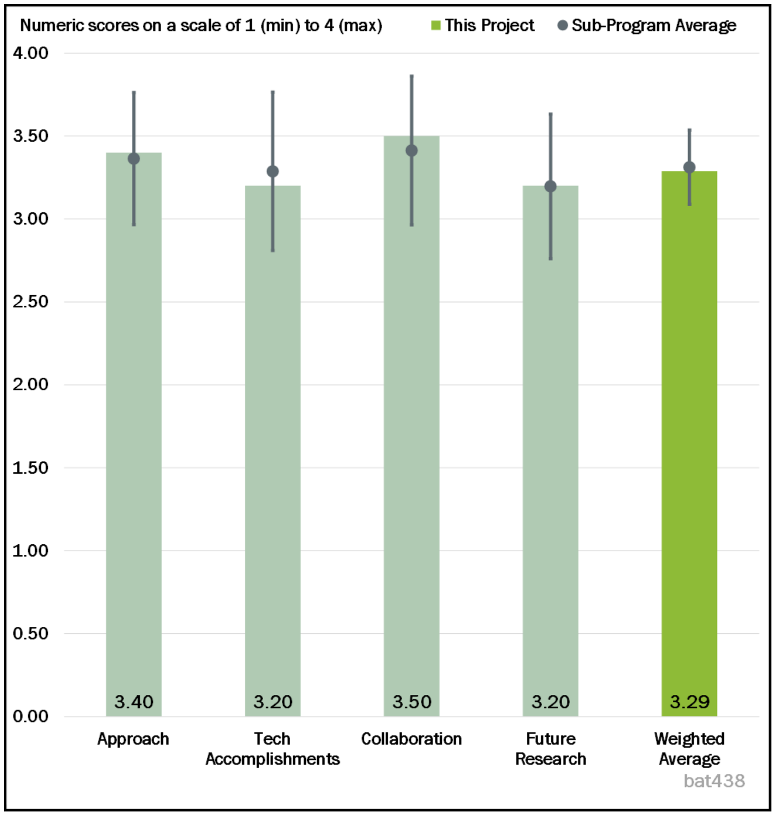

Figure 2-46 - Presentation Number: bat438 Presentation Title: Silicon Electrolyte Interface Stabilization (SEISTA): Advanced Characterization Principal Investigator: Glen Teeter (National Renewable Energy Laboratory

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, the approach to investigating the surface of Si particles for Li- battery anodes is excellent. The team uses many different in situ and ex situ techniques for investigation of these important materials. Many of these techniques utilized the resources of the National Laboratories and have had little application toward battery materials. This approach utilizes the novel expertise of the team to develop a better understanding of these important battery materials.

Reviewer 2:

This part of the SEISTA program hits at one of core issues for Si stability (characterization) and aims to conduct in situ and in operando characterization of materials. These characterization techniques are important because they provide the best insight into the operating cells.

Reviewer 3:

The approaches involve cutting-edge tools to characterize the Si electrode.

Reviewer 4:

The development of many useful characterization techniques for such difficult systems is extremely valuable. The reviewer did not think the presentation showed enough how those techniques have helped answer any questions about Si failure mechanisms. For example, the XPS in situ lithiation of SiO_x-Si showed how the composition affects the over-potential. It would be good to then relate this to what might happen in a real cell for various Si-active materials.

Reviewer 5:
The reviewer is very much in favor of calendar-life studies, where breakthroughs in performance and understanding seem more likely than in cycle life, which has been studied intensely already. But the reviewer saw no work on it.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The advanced characterization tools used (neutron reflectometry, surface-enhanced Raman spectroscopy [SERS], XPS, etc.) here are exceptionally suitable to shed light on the fundamental processes at Si-electrolyte interfaces. The data are very insightful and SOA. Very impressive!

Reviewer 2:
Many of the novel techniques utilized provide significant new results and understanding of the SI SEI. The in-situ SERS provides interesting insight into the formation, dissolution, and decomposition of the SEI on Si anodes. Related matrix-assisted laser desorption/ionization time-of-flight investigations of electrolytes containing vinylene carbonate reveal systematic changes to the SEI, including the generation of polymeric and oligomeric species. These results are both interesting and novel. In particular, the novel in situ XPS results provide significant insight into the evolution of the Si surface upon lithiation and delithiation.

Reviewer 3:
Significant results were shown although they did not seem to be distilled into conclusions or concrete results. The reviewer was left wondering what the Impact was of the tests or how to use the characterization results to design better materials and move the industry forward. For example, there was not much discussion of the impact or takeaways of using the in-situ neutron reflectometry experiment or what the team hoped to achieve with the investigation; the story is similar for the in-situ SERS.

Although the work is great, it was not clear to the reviewer what the Progress or Accomplishments were with the investigations. There was a slight bit of connection between the time of flight - secondary ion mass spectroscopy measurements and the XPS analysis but any new learnings or breakthroughs are lacking. The most interesting results (Li diffusion along the Si-silicon oxide interface) may have been due to impurities and were not substantially investigated.

Reviewer 4:
Again, the reviewer found good progress on the development of techniques. But those techniques now need to be applied to the right systems to address the issues on Slide 3.

Reviewer 5:
A microbalance can measure the thickness of SEI, operando, with much more sensitivity and much greater ease than neutrons.

The focus here on SEI composition brings up this question: After so many studies of SEI composition, have we learned anything useful? Why does the team expect useful results to come from Si-SEI studies?

The Li+ ion gun is novel and sounds exciting. But the reviewer does not understand what the team is learning that can apply to Si electrodes.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project is characterized by excellent collaboration among the team members.

Reviewer 2:
There is good collaboration between teams across the project. The reviewer noted that work was spread out between organizations and participating partners and was highlighted in the presentation.

Reviewer 3:
The results presented are part of a multi-laboratory collaboration. The collaboration and coordination between National Laboratories are good and has afforded the generation of novel and important results.

Reviewer 4:
This project involves a lot of techniques, which necessitates different researchers with different expertise. The group seems to be working well together to deliver advanced characterization techniques to this effort.

Reviewer 5:
The reviewer is not sure that this project benefits from cross-pollination of ideas between labs; each project seems to be working on its own.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The presenter highlighted the expected transition to "real-world" samples and the need to conduct "future studies on model systems where they can provide clear answers to key questions." The reviewer found that statement to be extremely important and suggested that significant effort should not be applied to studies where there are not clear learnings that can be used to advance fundamental understanding. Future work is headed in the right direction, but there is no mention of decision points or alternative development pathways to ensure the team is focusing on the most promising techniques to solve pressing issues.

Reviewer 2:
The proposed work is a continuation of the results that have been generated. The team will continue to expand the utilization of the novel techniques developed for the investigation of Si anodes. These additional investigations will likely lead to the generation of additional important observations.

Reviewer 3:
The reviewer focused on bullet point #3 on the Future Work slide. That might not yet be possible with all the techniques, but the team could prioritize those that are most mature.

Reviewer 4:
These tools are great, but the reviewer was not sure the overall DOE objective for this project will be achieved by this work (of the whole effort).

Reviewer 5:
The reviewer found the proposed projects on Slide 18 to be vague: "Future studies on model systems will continue where they can provide clear answers to key questions."

There are lots of composition measurements already in the literature about SEI species. What new is the team expecting from these experiments? What will the team do with the information that it gets?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer remarked that LIBs are critical to our energy independence, and Si plays a large role in improving EV adoption by decreasing battery costs. In order to accelerate Si adoption, a fundamental

understanding of the materials must be achieved. This project aims to improve the fundamental characterization of Si.

Reviewer 2:
This project supports the DOE objectives of developing lower cost, higher energy density LIBs for electric vehicles. The development of improved Si or Si-graphite composite anodes is one of the few viable methods to increase the energy density of the anode for LIBs. This team is addressing the important problems in an appropriate manner.

Reviewer 3:
The reviewer stated that Si anodes are an important component in achieving DOE roadmap energy-density targets. This project seeks to understand and improve the performance of Si.

Reviewer 4:
The project supports the overall world doing objective by improving Si anode.

Reviewer 5:
The project is relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources and time given to this project were significant and sufficient.

Reviewer 2:
The resources seemed appropriate to the reviewer to achieve the stated milestones. There is access to enough resources (time, money, and equipment) to make significant progress toward milestones. The projects just have to be well designed, managed, and stage-gated to increase probability of success.

Reviewer 3:
This is a big team, and resources seem adequate to continue.

Reviewer 4:
Resources are sufficient.

Reviewer 5:
The project is properly resourced.

Presentation Number: bat439
Presentation Title: Silicon Deep Dive: Silicon-Based Slurries and Electrodes
Principal Investigator: Beth Armstrong (Oak Ridge National Laboratory)

Presenter

Beth Armstrong, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

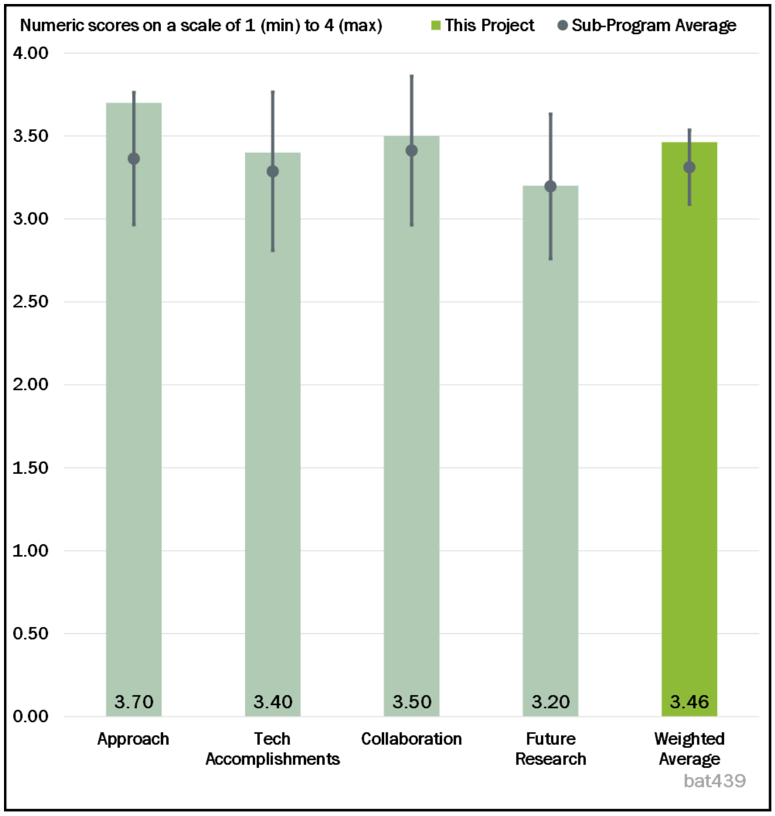

Figure 2-47 - Presentation Number: bat439 Presentation Title: Silicon Deep Dive: Silicon-Based Slurries and Electrodes Principal Investigator: Beth Armstrong (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that this was a very well planned and focused project that tried to better understand the factors that govern Si-anode coating variables, which are very critical to developing very stable Si electrodes.

Reviewer 2:

The presenter sufficiently described an approach to improving Si-based slurries and electrodes. Technical barriers were addressed (consistent protocols, electrode rheology, and additives to control attractive forces). The project appeared to the reviewer to be well designed and feasible and details the characterization methods used to conduct the project.

Reviewer 3:

The approach to systematically investigate the interrelations between the liquid-solid interfaces to control electrode homogeneity and performance is very important to the battery community. The utilization of a multi-laboratory effort to develop consistent protocols and develop a better understanding of processing is critical for battery applications in electric vehicles. In addition, since surface modification of Si particles has recently developed as an important area for material-performance enhancement, developing a better understanding of surface modification on rheology is important.

Reviewer 4:

Rheology has not been beaten to death in the literature like so many other efforts to improve batteries. Studying homogeneity is important.

Reviewer 5:
It is critically important to understand the slurry and casting process of electrodes. The reviewer asserted that we do not sponsor enough of this. The work on recovery time is very important to today's manufacturers and can be an important means to get better battery performance.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer praised the accomplishments and progress as excellent. The work on how the Si surface changes the aggregation and structure of the binder in solution is particularly interesting and can be applied to commercial systems. This is immediately useful to industry.

Reviewer 2:
This project has led to quite a few very impressive results and insights that will be highly useful in developing a very efficient Si electrode. The studies on stress, rheology, and binder behavior as a function of Si-surface properties; use of tomography; and Si-surface functionalization have been nicely carried out and results lucidly explained.

Reviewer 3:
The technical accomplishments are strong. Binders have been reported to have a large influence on the properties of Si anodes. The results suggest that the surface of the Si particles has a large effect on aggregation and binder structure. The results also show that optimization of the mixing and slurry chemistry can be used to optimize electrode homogeneity. Both of these results are important for the development of Si anodes for LIBs.

Reviewer 4:
The reviewer asked how electrode homogeneity affects battery durability or other battery properties. In general, how does the team relate these measurements to performance? The reviewer thanked the project team for trying not to repeat what the reviewers have already seen in other talks. Additionally, the reviewer commented that rheology analysis is very valuable for improving how electrodes can be made more reproducible. Unless cesium (Cs) is well dispersed in the binder, using Cs to locate binder is flawed.

Reviewer 5:
The presenter described technical accomplishments in regard to electrode development although the reviewer noted that significant questions remain. There are many variables that must be covered to ensure appropriate electrode formulation (adhesion, cohesion, peel strength, porosity, inactive volume, electrical resistance, thermal resistance, etc.), which did not seem to be taken into account with the data presented in the technical accomplishments.

There is no linkage between the mixing procedure to produce these laboratory-scale electrodes and those that are produced at a pilot scale and/or commercial level. The results shown in the presentation may not be relevant to practical mixing equipment.

The characterization results (X-ray nanotomography, rheology, etc.) were interesting and well done, but more effort must be exerted to ensure that electrodes are completely mixed properly and are applicable to practical equipment. For example, commercial applications typically do not use more than 1% carbon black anymore and often use very small amounts of carbon nanotubes (CNTs). Therefore, some of the X-ray nanotomography and rheology results are not broadly applicable beyond this specific project and the electrodes that were prepared. Additional characterization techniques (electrical resistance, impedance, etc.) could have also been used to determine the quality of electrode coatings.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project made efficient use of the expertise of the collaborating team members for synthesis, analysis, and modeling, among others.

Reviewer 2:
This is a multi-laboratory effort, which clearly utilizes much collaboration and coordination. The team has done a good job with coordinating the different efforts.

Reviewer 3:
The large team is fairly well coordinated, and communication looked appropriate to the reviewer.

Reviewer 4:
The reviewer found good collaboration across laboratories.

Reviewer 5:
There appears to be good collaboration and coordination across projects. Although it was not explicitly mentioned in the presentation, significant collaboration between ORNL and ANL's Cell Analysis, Modeling, and Prototyping (CAMP) Facility could prove beneficial for electrode and slurry-processing development.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future research on rheology, surface modifications, or process improvements will contribute well to the body of good data developed so far.

Reviewer 2:
The future direction is oriented toward developing a better understanding of the relationship of SEI stability on electrode formulation. The reviewer noted that this will be one of the critical areas for further developing Si anodes. The team will also direct effort toward the development of better processing methods in order to generate more homogeneous laminates. These efforts are also important for the development of Si anodes for Li batteries for electric vehicles.

Reviewer 3:
The reviewer said that this is a good approach to continue. It would be good to always compare with results from a standard graphite system. Are the observed results and relationships unique to Si?

Reviewer 4:
Proposed future research was appropriate although somewhat vague and high level (for example, "Continuous feedback to team doing fundamental work."). The reviewer suggested that project members reach out to cell-manufacturing experts to learn more about critical processing parameters to accelerate learnings. This project has access to very powerful equipment and should be applied to cutting-edge electrodes and materials. The presenter was aware of some of these issues and acknowledged some of them on the Critical Assumptions & Issues slide so they can hopefully be addressed soon.

Reviewer 5:
Most of the future research statements are pretty vague: for example, on Slide 18, "Understanding of rheology and impact on formulation and performance." What, specifically, does that mean?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This work is very relevant to the DOE overall objectives since an improved Si anode will lead to increased cell energy density ability.

Reviewer 2:
This project is relevant because it is focused on Si-anode technology, which has been identified as a key driver to decrease battery costs and increase EV adoption (a key DOE objective).

Reviewer 3:
This project supports the DOE objectives of developing lower cost, higher energy density LIBs for electric vehicles. The development of improved Si or Si-graphite composite anodes is one of the few viable methods to increase the energy density of the anode for LIBs. This team is addressing the important problems in an appropriate manner.

Reviewer 4:
The reviewer stated that Si is an important component to achieve DOE's energy-density roadmap for automotive applications. There needs to be more understanding to get Si to work and achieve targets.

Reviewer 5:
The reviewer said that the project is relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources allocated to this project are significant and sufficient.

Reviewer 2:
Resources are appropriate and sufficient to achieve program milestones.

Reviewer 3:
The project is sufficiently resourced.

Reviewer 4:
Resources seemed sufficient to the reviewer.

Reviewer 5:
The reviewer commented that resources are sufficient.

Presentation Number: bat440
Presentation Title: Silicon Deep Dive: Silicon Functionalization
Principal Investigator: Zhengcheng Zhang (Argonne National Laboratory)

Presenter

Zhengcheng Zhang, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

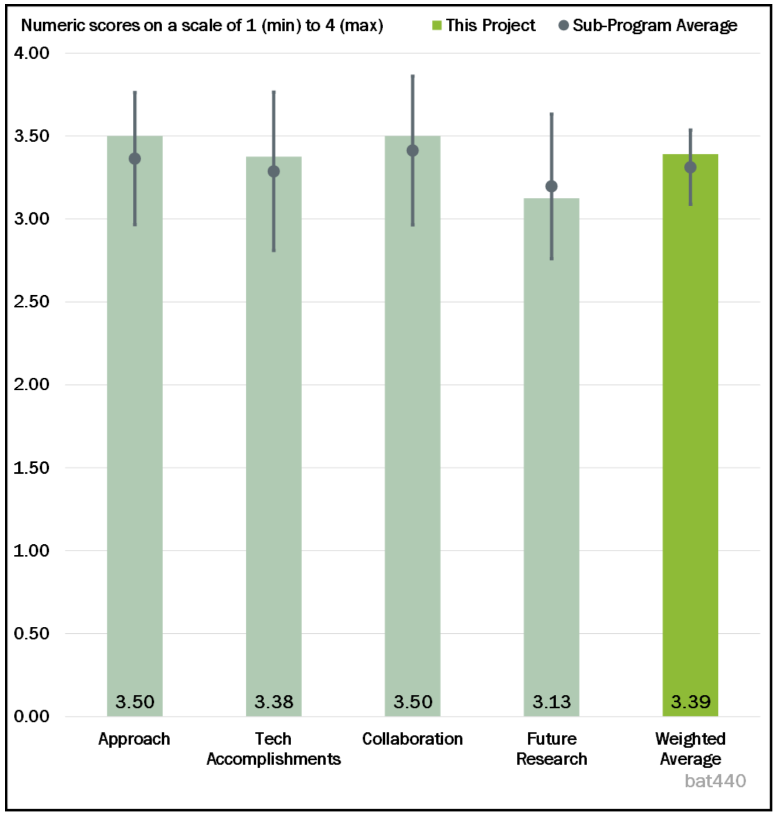

Figure 2-48 - Presentation Number: bat440 Presentation Title: Silicon Deep Dive: Silicon Functionalization Principal Investigator: Zhengcheng Zhang (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The presenter focused on two main strategies to improve materials performance—active-material surface stability and electrolyte development. These strategies provide a practical approach to improving materials performance in categories that are most likely to improve Si-anode performance (SEI improvement). Strategies address key technical barriers (calendar life and cycle life), and the reviewer remarked that the project appears well designed and feasible.

Reviewer 2:

The reviewer stated that the approach to surface modify Si particles to improve the interfacial properties is both interesting and useful. The proposed method to etch the surface to generate Si-H bonds followed by hydrosilylation reactions utilized well-developed synthetic methods to make functional materials. The choice of different types of grafting agents is useful for the systematic development and investigation of novel materials.

Reviewer 3:

The concept of functionalizing Si nanoparticles to create an SEI could be a good approach, according to the reviewer. The systematic evaluation of functional groups that are expected to perform in different ways looks very effective. It would be good to show that the functional groups help on the varying types of Si.

Reviewer 4:

Numerous studies have functionalized Si nanoparticles. The reviewer would like to have seen what is new and/or different here—some comparison to what is already in the literature.

Looking for new electrolytes is very valuable.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The presenter provided impressive results on surface modification of Si particles and the resulting electrochemical performance. The reviewer observed that Si particles treated with various materials (ethyl carbonate, epoxy, ethylene oxide, etc.) seemed to show major increases in the average CE, which should translate to improved SEI and Si-cycle life. Surface modification led to reduced electrode swelling and reduces impedance growth. As a follow-up, it would be interesting to learn if the surface-modified Si materials also suffer from the “SEI dissolution” issues described in other projects. It would also be interesting to investigate if these surface modifications lead to thinner and more stable SEIs (especially the epoxy-modified Si particles), or if these materials can be integrated with the Mg-salt addition (Zintl phase) to also further compound improvements to SEI and cycle life.

Additionally, the work on the high-concentration electrolytes, fluorinated ethers, and deep eutectic solvents appeared unique and promising. The presenter described results showing 500 cycles to 80% capacity retention, which is impressive although it was not clear to the reviewer if these would provide a practical energy-density improvement in their current format. Most importantly, it would be good to know how these electrolytes behave for improving calendar life—one of the key barriers the team is addressing with this project.

Reviewer 2:

This project had a lot of work done on it, with sound conclusions. It involved functionalization of the particles, characterization, and testing, which means a lot of effort every time the chemistry is changed. There are good accomplishments.

Reviewer 3:

The technical accomplishments are interesting and beneficial. A series of different sidechains were grafted onto the Si particles. The reactions appear to generate novel surface films, and some of the novel surface films provide performance enhancements. The team was also able to generate mixed surface films, which are quite interesting. According to the reviewer, the team should have commented on the potential cost of these surface modifications and whether this can be done in a cost-effective manner. The novel electrolyte formulations are also interesting and show promising results.

Reviewer 4:

The reviewer offered the following comments and questions:

- Hybrid, functionalized Si nanoparticles are a terrific idea, but the first cycle loss is too high and CE is too low. How can this approach be improved?
- The new electrolyte shows good life, but specific capacity (Slide 15) is extremely low, around 100 mAh/g. Why? Is there a zero missing from the y-axis?
- Is there any work on calendar life? Should not the calendar-life work be the first project to get attention so that the experiments can last for a few years?
- It was not clear how much of the SEI problems are due to chemistry and how much to mechanics. Is this issue being considered?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The presenter highlighted good collaboration across the six DOE National Laboratories for this integrated effort. Also, there was explicit mention of coordination between ANL core facilities and with interactions within the Si Deep Dive program.

Reviewer 2:
The project is a collaboration between multiple National Laboratories. There appears to be both good coordination and much collaboration within this project, according to the reviewer.

Reviewer 3:
This project has a lot of people collaborating and seems to coordinate well. In particular, the reviewer thought that this project covered a lot of different skill sets.

Reviewer 4:
The reviewer remarked that five to six labs are participating.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future research builds on the existing projects and provides directionally clear work to be performed. The reviewer stated that the proposed research did not discuss specifics, risk mitigants, or decision points for stage-gating projects moving forward.

Reviewer 2:
The reviewer suggested trying more functional groups to gain understanding and improvement before spending a lot of time on scale-up.

Reviewer 3:
The reviewer said that no specifics are provided.

Reviewer 4:
While the team proposed to continue the investigation of surface-modified Si particles and the development of novel electrolytes, the team could have provided more specific directions for the future research.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is relevant because it is focused on battery technology, which is a critical national security issue and key to achieving U.S. energy independence. The reviewer noted that Si-anode technology is required to achieve LIB cost thresholds to compete with IC engines for EVs. This project aims to accelerate Si development, thereby accelerating EV adoption and improving U.S. global competitiveness in energy storage.

Reviewer 2:
This project supports the DOE objectives of developing lower cost, higher energy density LIBs for electric vehicles. The development of improved Si or Si-graphite composite anodes is one of the few viable methods to increase the energy density of the anode for LIBs. This team is addressing the important problems in an appropriate manner.

Reviewer 3:
The reviewer remarked that Si anodes are an important component in the DOE roadmap for improved energy density for automotive applications. The issues with Si have not been solved even though a lot of work has been done. This work supports fundamental understanding required to ultimately solve the problems.

Reviewer 4:
The reviewer said that Si electrodes are relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources seemed sufficient to the reviewer and appropriate for this multi-organization project spanning six National Laboratories and additional academic partners.

Reviewer 2:
Resources are sufficient.

Reviewer 3:
The project is sufficiently resourced.

Reviewer 4:
Overall, the reviewer thought that the Si-anode Deep Dive has enough resources and would like to see this specific effort enhanced over some of the others.

Presentation Number: bat441
Presentation Title: High-Performance Electrolyte for Lithium-Nickel-Manganese Oxide (LNMO)/Lithium-Titanate (LTO) Batteries
Principal Investigator: Jennifer Hoffman (Gotion)

Presenter

Jennifer Hoffman, Gotion

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers indicated that the resources were sufficient, 20% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

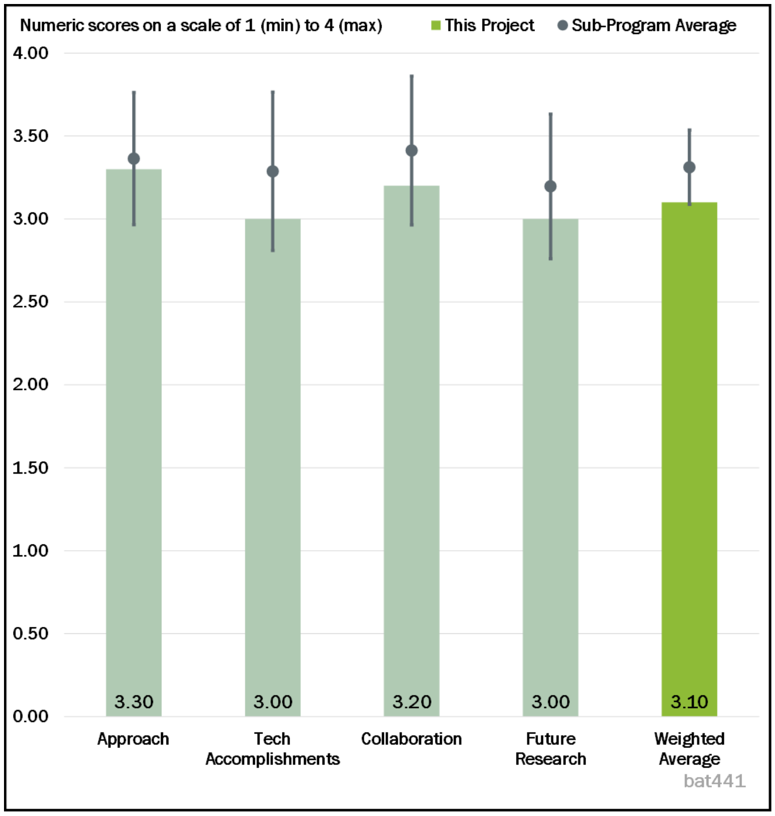

Figure 2-49 - Figure 2 49 - Presentation Number: bat441 Presentation Title: High-Performance Electrolyte for Lithium-Nickel-Manganese Oxide (LNMO)/Lithium-Titanate (LTO) Batteries Principal Investigator: Jennifer Hoffman (Gotion)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer praised the approach as the best one seen so far. The team plans to investigate a number of additives for a number of different properties, including conductivity, stability, and gas suppression. It hopes to learn what aspects of the additives lead to what types of impacts on critical electrolyte properties.

Reviewer 2:

The project team has identified the critical technical and cost barriers associated with the Li batteries. The reviewer stated that the relevance of the objectives and its impact is clearly mentioned. The team has developed a multi-layer, pouch-cell test to understand the intricate details and documented it well. This is a well-designed and feasible approach.

Reviewer 3:

The main strategy of the project is to select and synthesize electrolytes that work best for a LMNO-lithium titanate (LTO) battery. The team's major approach, as seen in the presentation, is routine tests on the electrolyte properties and electrochemical performance. The reviewer remarked that this might be a feasible route but not with novel technologies.

Reviewer 4:

The reviewer appreciated the approach being taken but wondered what about this approach is novel compared to historical attempts to overcome these challenges. The difference in this project compared to the past should be called out in the future.

Reviewer 5:
The project aims to enable LTO-LNMO battery chemistry as a way to overcome performance barriers for high energy density and long life as well as address the cost barrier to the high-performance batteries needed in longer range EVs. The limited scope of the project, however, limits its ability to address the performance barriers, and there is really no obvious way the work will address the cost barrier based on the information provided.

On the latter cost goal, the only reference to cost was that LTO is more expensive than graphite, and LNMO is potentially cheaper than NMC622 due to zero Co, with the trade-off in costs potentially being slightly favorable, perhaps? A later reference in the property gap chart indicated that electrolyte costs are to be less than $10/kg, but it was certainly not clear to the reviewer how the cost barrier of high-performance batteries will be addressed by small tradeoffs in the cost of materials. Furthermore, the cost advantage of LNMO will start to decrease as NMC811 is adopted and/or other low-Co cathodes. There may not be much room for cost reduction here.

For the first barrier of high-energy-density performance, the selection of LTO-LNMO is a reasonable choice to address the barrier, but the project’s almost sole focus on electrolyte additives to solve all of the problems (some of which are clearly popping up in the early tests with LNMO/C) is a bit shortsighted. If the problems with high-voltage cathodes (and LTO as well) were limited to gassing, then this approach would probably be fine.

The reviewer asserted that the team on this project is excellent, and the University of Rhode Island (URI) in particular is a well-known leader in studying and mitigating gassing reactions. There is no one better to take on gassing issues. But, the instability of the electrolyte with high-voltage cathodes involves far more coupled, non-equilibrium electrochemistry and calls for a more comprehensive approach to solving the problem than hoping that an additive package can stop gassing and passivate the surface of the LNMO.

The work here will contribute to the solution in all likelihood, but it is unlikely to make much headway against the high-energy-density/long-cycle-life barrier by itself. In the end, the team will be able to screen about a dozen additives, have to down-select that list based on what can be scaled in synthesis, further down-select that list by what showed promise in the screening, and get to test only one, two, or maybe three additives in 2-Ah and 10-Ah multi-layer pouch cells (MLPCs).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Overall, the reviewer said that the technical accomplishments for the project are good. The gap chart for advanced electrolytes and performance parameters is clearly populated, and the investigative approach to understand the performance of each parameter is clearly mentioned. The team has showed good technical progress measured against the performance indicators.

Reviewer 2:
Some additives improve one aspect of the electrolyte while others help another aspect. The team is still searching for the optimal additive.

Reviewer 3:
Work is ongoing as is in-depth analysis. Some initial correlations are seen. More work is needed for structure-property relationships.

Reviewer 4:
Because of the impact of COVID-19 and U.S.-China relations, some of the tasks were delayed or extended.

Reviewer 5:
The project has made some progress: for example, an additive (one of three tried) for reducing LTO gassing was found. The approach of using NMC622 as the cathode in these tests to isolate the LTO-gassing performance was very good. The corresponding 2-Ah pouch cells were tested and showed good results, another positive step in the right direction. However, the reviewer stated that progress on the LNMO (isolated testing with C as the anode) does not seem to have fared well, and results for these tests (Slide 9) were notably poor. The team claimed that progress was still made because it learned a lot about the gassing and other degradation mechanisms, but this vague assertion is hard to quantify. It does not seem to have triggered a new innovative idea for an additive, at least not one that was mentioned. So, the progress of the project is going to be affected by these results.

The LNMO/C cells were on the project's critical path and a delay in this work while the problems are worked out will also delay the end of the project. Progress on measuring the intrinsic properties of the electrolyte was also made, but again it was not clear to the reviewer if any progress was made on optimizing and/or balancing the obvious tradeoffs, like specific conductivity versus vapor pressure. Slide 8 has lots of yellow, but also has some gray where apparently measurements have yet to be made.

As a note to the team, the Overview slide says that the project runs from March 2019 to March 2022, which is a 3-year time frame, but the PI said that it was a 2-year project. The PI also said, "it's still early in the project" and "when we get to the middle or nearer the end of the project." If the project is indeed 2 years, then the project is past its mid-point, and progress will have to be greatly accelerated to even fully characterize the performance advantages of the electrolyte additives that have already been identified as potentially beneficial in an actual LTO-LNMO cell.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The team is working with Brett Lucht's group at URI in trying to understand the impact of different additives.

Reviewer 2:
The team seems to rely on each member to move the project forward.

Reviewer 3:
The collaboration and coordination between Gotion and URI appear to be very good. It was not clear to the reviewer how much of the work is being done where, but the pace of activities does not seem to be limited by the logistics of such a collaboration. This is not always the case in even a two-partner collaboration, so it is good to see that the partnership seems to be doing very well.

The problem with 10-Ah testing was not really clear. Was it vaguely due to some issues with Gotion's expansion overseas? Anyway, URI is probably well positioned to find the necessary resources for its partner if the current plan also fails to work out.

Reviewer 4:
The reviewer stated that the involvement of an academic institution in this collaborative effort is good in terms of understanding the fundamental aspects, but the addition of DOE National Laboratories would enhance the development process.

Reviewer 5:
Collaboration with URI is declared, but no activities are reported so far and the project is said to be already 45% completed (which is an exaggerated statement).

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The overall approach proposed for future research seemed okay to the reviewer; however, the key step as to why this will suddenly lead to an improvement not yet achieved by others is missing.

Reviewer 2:
The reviewer did not see any difference between the Approach and the Proposed Future Research. There is a slight difference in electrolyte intrinsic property study between the Approach and proposed future study.

Reviewer 3:
The tasks listed in the "Approach" slide about MLPC testing are exactly the same as that in the slide for Proposed Future Research. The reviewer could not tell which parts are completed and which parts are future works. The poster was not carefully prepared.

Reviewer 4:
The team still needs to test additional additives in NMO/C and NMO/LTO cells. This methodical approach is critical to finding an answer, according to the reviewer.

Reviewer 5:
The apparent plan is to move ahead with the 2-Ah MLPC with LTO-LNMO in parallel with continuing the C/LNMO work to solve the capacity-loss issues observed so far. It was not clear to the reviewer that parallel development will be all that effective or useful. How can the LTO/LNMO cells be properly evaluated if major issues with electrolyte stability with the LNMO cathode at 4.9 V have not been addressed?

It was also not clear to the reviewer, with the time remaining, that the 10-Ah MLPC test can be completed as envisioned. This might be a good time to take stock of the progress to date and the opportunities to address the most significant issues in a reasonably large pouch cell and restructure the project to focus on the highest impact outcomes. Making a 10-Ah MLPC that is not likely to cycle longer than 100-200 cycles due to electrolyte decomposition, CEI formation, impedance rise, etc., at the cathode might not be the best plan going forward.

It is not really clear what the team has learned in the initial tests (details were withheld), but it is not likely that enough was learned to regain the original schedule and finish all of the planned testing within the original time frame of the project. This is just a guess based on the information in the poster.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project clearly supports and is well aligned with specific DOE objectives for advancing EV battery technology and enabling vehicle electrification. As some point, high-energy cathodes (e.g., 4.9 V) will have to be commercialized to support ever-increasing performance requirements for EV batteries, and this work could provide at least a portion of the answer if a few beneficial additives for LTO and/or LNMO can be identified and demonstrated at some level of testing.

Reviewer 2:
The reviewer noted that the objective of the project is to boost performance of LNMO-LTO batteries, which supports the DOE objective.

Reviewer 3:
Developing a fundamental understanding of high-voltage stability and improved conductivity of electrolytes with additives is critical to advancing many novel, high-energy systems, which are critical to DOE's mission.

Reviewer 4:
Electrolyte development is critical for DOE to achieve its electric vehicle targets.

Reviewer 5:
The reviewer said that the research presented does meet the DOE overall objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project team has allocated sufficient resources to perform the research and achieve the stated milestones in a timely fashion, according to the reviewer.

Reviewer 2:
The reviewer asserted that the $1.5 million in DOE support is enough for all these proposed routine tests.

Reviewer 3:
The resources available have allowed for meaningful advancement.

Reviewer 4:
Resources are sufficient.

Reviewer 5:
It is possible that the resources (funding) are available to complete the project and achieve key milestones, but an extension of the project timeline is probably going to be required (partially due to pandemic shutdowns on laboratories).

Presentation Number: bat442
Presentation Title: Behind-the-Meter-Storage (BTMS) Overview
Principal Investigator: Anthony Burrell (National Renewable Energy Laboratory)

Presenter

Anthony Burrell, National Renewable Energy Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 50% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

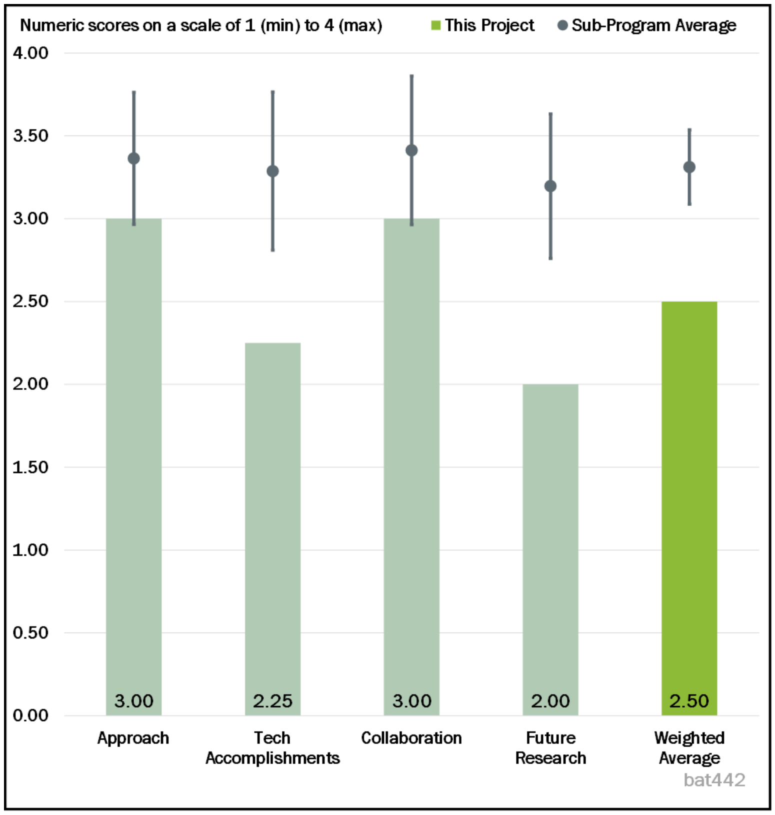

Figure 2-50 - Presentation Number: bat442 Presentation Title: Behind-the-Meter-Storage (BTMS) Overview Principal Investigator: Anthony Burrell (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The PI did an excellent job of describing the breadth of the challenge. What could be improved is the definition of what success on the project would look like. An example of a quantitative assessment would be helpful. It will otherwise be difficult to assess when the project is complete.

Reviewer 2:

Most of the presentation was an overview of the problem and what they hoped to address. The role of each National Laboratory was not clear to the reviewer. How the money was distributed was not mentioned nor were deliverables defined. The presenter basically said it is a large, complicated problem that will require a lot of work for a solution and made it clear that this is not a battery for the grid nor is it a battery for a vehicle. It is some form of energy storage for a combination of photovoltaics (PV), building loads, and EV fast-charge requirements. The team needs to figure out the value proposition of such a system.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

This is a $2.5 million project with four National Laboratories, and the team is basically still laying out the problem. The reviewer saw very few accomplishments after a year and a half of effort. If funded at $2.5 million in 2019, that’s nearly $4 million. Essentially, the team has defined a problem so complicated that it did not appear to the reviewer that the team knows where to start or how to solve it. This should have been funded at a much lower level until the team figured this out.

Reviewer 2:
There are several parallel work streams. The reviewer said that it would be helpful to have shown, for each work stream, the targeted deliverables and decision points over the length of the project. The PI could better describe how results from the individual work streams are synthesized. An example would be the down-selection of the electrochemical storage technology and the thermal energy storage technology, and then how those two would be optimized, given the constraint of the big box store, mall problem.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Coordination appeared to be good. Highlighting who was taking the lead for each of the particular sub-projects would be beneficial. This could either be placed against the task on each slide, or provide a summary in the front, as to which participant is delivering what.

Reviewer 2:
The reviewer asserted that the collaboration is difficult to rate because work from any one institution was never pointed out. Again, most of the presentation was about the problem. How the problem was broken down and distributed to the different National Laboratories is never discussed.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer referred to prior comments while stating that the PI should be clear on how the parallel paths will be synthesized, as well as what the major risks are on each of the parallel paths. A slide describing how negative outcomes and positive outcomes can be gamed in order to determine potential best solutions would be helpful.

Reviewer 2:
There was no future directions slide. There was some analysis of how to treat thermal energy storage and how it was analogous to electrical energy storage, but there were no clear tasks laid out as to next steps and who would be doing what.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is an excellent example of balancing multiple key technologies' developments with the overall DOE objectives.

Reviewer 2:
The reviewer assumed that the DOE objectives are to move to a sustainable ecosystem. Trying to figure out how to do this while satisfying the needs of everyone is a huge challenge. These folks have identified a particularly difficult barrier that is worth investigating.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project appears to be adequately staffed and supported. The project could spin off additional projects, however, and then those need to be evaluated for appropriate staffing and support.

Reviewer 2:

The reviewer's guess was that most of this early work is being conducted at NREL, but from the presentation it is anybody's guess. The reviewer had no idea how many folks are working on this problem, but it is quite a large budget. The reviewer was not sure how the team is going to see itself to the end. It seems that perhaps after 3 years the team will have the problem mapped out where it can start coming up with some design parameters for the entire system.

Presentation Number: bat444
Presentation Title: Highly Loaded Sulfur Cathode, Coated Separator, and Gel Electrolyte for High-Rate Lithium-Sulfur Battery
Principal Investigator: Yong Joo (Cornell University)

Presenter

Yong Joo, Cornell University

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

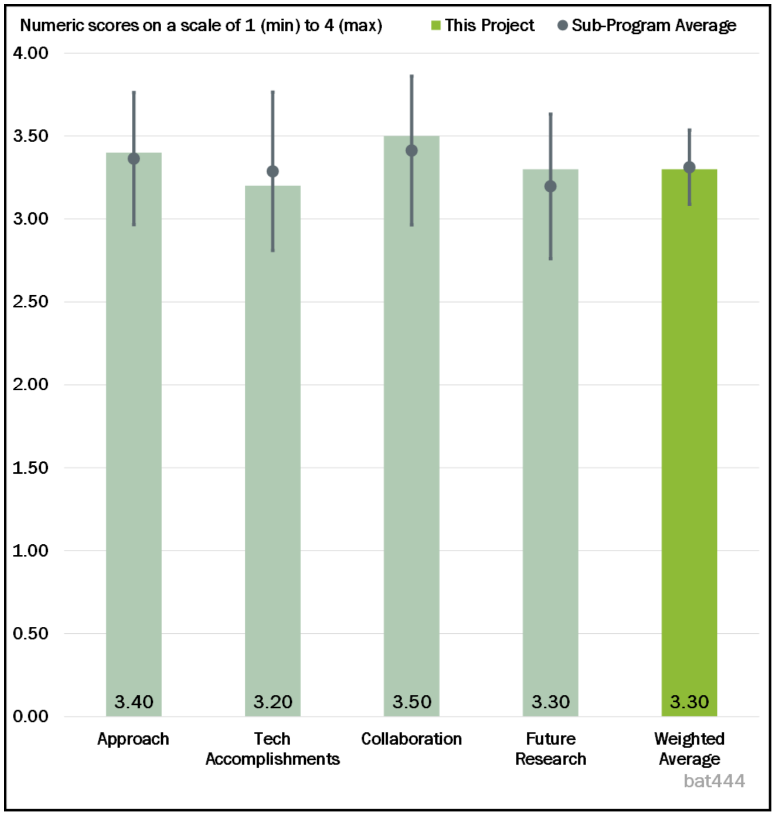

Figure 2-51 - - Presentation Number: bat444 Presentation Title: Highly Loaded Sulfur Cathode, Coated Separator, and Gel Electrolyte for High-Rate Lithium-Sulfur Battery Principal Investigator: Yong Joo (Cornell University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

There are multiple approaches in this work to develop a high-loading, high-rate, and longer cycle life Li-S battery.

The approaches include layer-on-layer electrospray method, graphene and ceramic separators, and gel electrolyte to prevent polysulfide dissolution and prolong cycle life.

The approaches are comprehensive and on multiple fronts to address the common issues in the Li-S battery.

Reviewer 2:

The project team used three approaches to overcome some key barriers of a S system. The method of incorporating S in graphene is novel and creative. Coating the separator with carbon and gelling the electrolyte will reduce the shuttle effect but will not completely overcome this barrier. Also, use of Li metal is still a major issue that limits the cycle life. The expectation is that by applying these three approaches, one can extend the cycle life to 500 cycles, thus making this system potentially applicable in some applications.

Reviewer 3:

The target of the project is to achieve high-rate Li-S batteries at high-energy conditions. There are many scientific and engineering barriers that need to be addressed toward that target, such as high S loading, reaction kinetics of the S cathode, Li-ion transport in both the liquid electrolyte and solid products, and the shuttling reactions of Li-polysulfide. In this project, the reviewer stated that the PI is aware of the challenges and has proposed effective approaches to solve those barriers. For example, the team used an electrospray method for multiple-layer cathode preparation to enhance the cathode electronic conductivity, did separator coating to suppress polysulfide crossover, and employed a gel-electrolyte concept to trap polysulfide in the cathode side.

The reviewer said that one important point needs to be carefully considered when proposing the approaches: the impacts of the approaches on the cell energy. For example, S content in the whole cathode, electrode porosity, mass loading of the separator coating, total weight of the gel electrolyte, and liquid components should all be controlled and minimized in order to achieve the proposed energy of 500 Wh/kg.

Reviewer 4:
The PI and collaborators reported a graphene-coated separator and gel electrolyte to prevent or slow down the dissolved polysulfide ions reaching the Li anode. The research aims to mitigate the shuttle effect caused by the dissolved polysulfide species. The gas-assisted electrospinning process for the thin-layer coating seems to be working and could be scaled up to a production process. The gel electrolyte certainly can slow down the mass transfer of the polysulfide ions.

The reviewer asserted that the PI needs to explain better why a graphene-coated separator can block the migration of polysulfide ions. The electronic conductive coating could result in the cell shorting.

Reviewer 5:
The PI used a combination of S cathodes, separator modification, and gel electrolytes to significantly suppress the shuttle effect and improve the cycle life and rate performance. Nevertheless, the current, areal-capacity loading (less than 3 mAh/cm^2) and electrolyte-S ratio (not clear to the reviewer) both need to be further improved to increase the practical energy-density goal for Li-S batteries in the future.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The PI has made satisfactory technical accomplishments, according to the proposed milestones:

- The S cathode loading has been optimized through a layer-by-layer approach and graphene nanoribbon coating.
- The ceramic-polymer separator with graphene coating has been successfully fabricated and showed improved rate capability.
- Initiation of gel electrolytes for Li-S batteries.

Reviewer 2:
The team made good progress and is on track to complete the tasks and milestones on time.

For the electrode task, the reviewer found the results of 3-mg/cm^2 loading, S-electrode performance at 900 mAh/g at 0.2C rate to be quite reasonable. The team also demonstrated the effectiveness of layer-by-layer approach to enhance rate performance. For the separator task, the cell-testing results demonstrated the effectiveness of the hybrid separator. For the gel-electrolyte task, the gel electrolyte provides better performance than conventional electrolyte.

Reviewer 3:
The team has demonstrated the positive effect of each technique separately and will be combining the effect of the three concepts in future work. The reviewer noted that the team expects some good results.

Reviewer 4:
Overall, the PI has made good progress during the review period. The project team also achieved milestones on time and on track to accomplish all the required milestone for the remaining time of this fiscal year. The

electrospray technique was successfully used to prepare the multiple-layer S cathode and functional separator coating. The prepared S cathodes showed significantly improved cycling stability. The separators with functional coatings were able to suppress the polysulfide crossover. The S content in the whole electrode as well as the mass loading of separator coating should be provided for a clear justification. Also, the reviewer commented that the relative electrolyte amount, i.e., the electrolyte-S ratio for the cell test, should be provided.

For the ceramic cross-link gel electrolyte, the PI indicated that the gel electrolyte helped to improved capacity retention and rate capability. However, all the discharge curves provided in the report showed higher electrochemical polarization for the cells using a gel electrolyte compared with those with a liquid electrolyte.

Reviewer 5:
In comparison with the control cell, the approaches did cause better results in term of capacity retention during cycling. The 3 mg/cm^2 was adequate and 0.2C rate was lower than 0.5C, which was in the objective, but it demonstrated that 0.5C was attainable.

The pore-size distribution could be improved. The reviewer asked that, first, please use log scale X and, second, how was the electrode degassed and was S in it?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
According to the reviewer, the team is complementary and works closely with the tasks well defined for each team member.

Reviewer 2:
The reviewer commented that this is an excellent collaborative effort including academia and industry. The academic collaborator is from Cornell University, and the industry collaborator is from EIC Laboratories. Each collaborator is responsible for certain activities as defined in the Collaboration slide.

Reviewer 3:
The PI has excellent collaboration and coordination with university and industry partners. The reviewer suggested future collaborations with other Battery500 teams in order to accelerate the integration of the achieved success for a practical battery demonstration.

Reviewer 4:
The team is well balanced with academic investigation and full-cell, scale-up developments.

Reviewer 5:
The collaboration and coordination across the project team have not been well demonstrated yet.

The reviewer could not find any joint publications with the co-PI or other partners.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The team will study the combined effect of Si-graphene, carbon-coated separator, and the gelling of the electrolyte. The team has shown positive results for each process. The reviewer expected that the performance of the cell—based on the combined three technologies—should be interesting.

Reviewer 2:
The proposed future work on high-S loading electrode, gel electrolyte, and development of pouch cells is made up of all-important tasks to pursue.

The target performance is also defined for each task and milestone.

The reviewer said it is reasonable to anticipate that the team can achieve most of the target by the end of the project.

Reviewer 3:
The proposed future research plan is reasonable. Integration test of the electrode and separator assembly would be helpful to identify real challenges that need to be addressed. Before the cell-safety test, the reviewer suggested that the PI first demonstrate Li-S pouch cells with practical high energies by using the developed materials and technologies.

Reviewer 4:
The PIs plan to optimize the synergistic integration of all cell components and scale-up to a 3-Ah full-pouch cell in the future. The plan is consistent with the proposed milestones.

The question is the safety test. A safety test only makes sense if a well-engineered cell is made. So, the reviewer suggested doing the safety evaluation in the end.

Reviewer 5:
Increasing the areal S loading is for sure required to increase the practical energy density of Li-S batteries toward 500 Wh/kg.

However, the electrolytes-S ratio (weight of gel electrolytes in this project) needs to be significantly decreased.

The reviewer did not see a plan or consideration on this from the PI.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is very relevant to DOE's objective in energy storage: high energy, long lifetime, low cost, and use of earth-abundant materials.

Reviewer 2:
According to the reviewer, the development of long-lasting, high-energy-density Li-S batteries is clearly relevant to DOE goals.

Reviewer 3:
Given the high theoretical energy density and extremely low cost of S, Li-S battery technology is one of the most promising battery technologies for future vehicle electrification and even for grid energy storage.

Reviewer 4:
The project supports the overall DOE objective since it relates to the development of a high-energy, low-cost S system that can enable mass electrification of vehicles.

Reviewer 5:
This project has a plan to improve the electrochemical performance of Li-S batteries by increasing S loading, suppressing the shuttle effect, and enhancing the reaction kinetics.

With further optimization of the electrolyte- S ratio, the reviewer said it could potentially enable the DOE energy goal on Li-S batteries.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer believed that resources are sufficient to achieve the stated milestones in a timely fashion.

Reviewer 2:
The resource is sufficient to the work performed and planned.

Reviewer 3:
The PI at Cornell has adequate resources for the fundamental investigation and developments, while EIC has the capability of scale-up to pouch cells.

Reviewer 4:
The PI has all the resources for cathode preparation, separator modification, gel-electrolyte preparation, and pouch-cell fabrication.

Reviewer 5:
The reviewer commented that there are sufficient resources for the project to achieve the stated milestones in a timely fashion if the team closely works with the industrial partner or other Battery500 teams.

Presentation Number: bat445
Presentation Title: Multifunctional Lithium-Ion Conducting Interfacial Materials for Lithium-Metal Batteries
Principal Investigator: Donghai Wang (Penn State University)

Presenter

Donghai Wang, Penn State University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

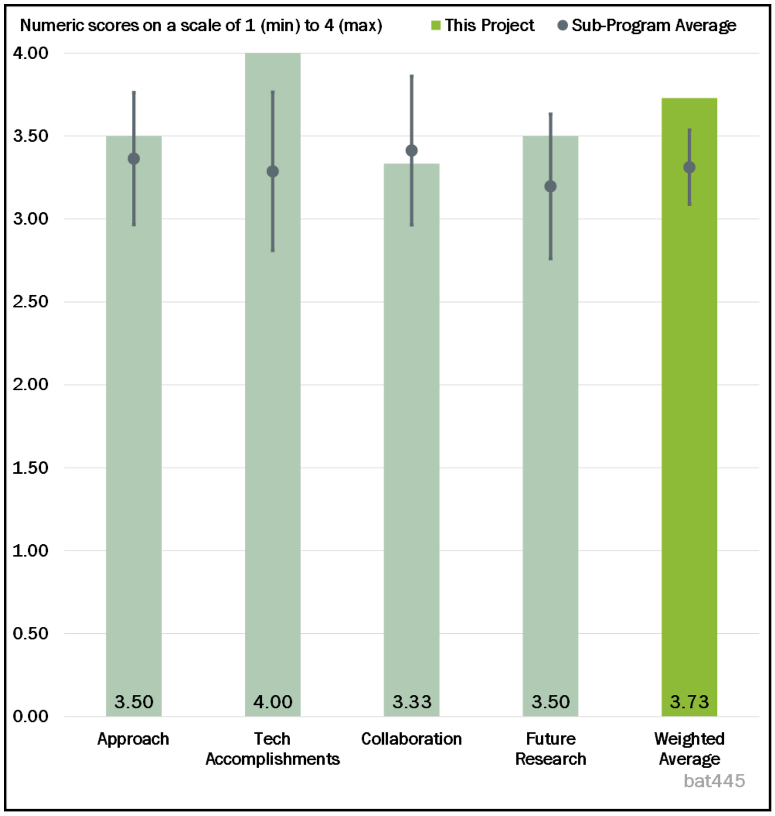

Figure 2-52 - Presentation Number: bat445 Presentation Title: Multifunctional Lithium-Ion Conducting Interfacial Materials for Lithium-Metal Batteries Principal Investigator: Donghai Wang (Penn State University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project is well designed with two approaches to overcome the technical barriers. First, a bottom-up design using a reactive polymer composite (RPC) to enable excellent cycling performance under lean electrolyte with limited Li excess and high capacity.

Second, using an electrochemically active monolayer (EAM) strategy to efficiently improve the Li-metal battery performance at low temperature (-15°C). Suppressing dendrite formation during Li-metal deposition is very important for high-energy-density battery development but is an extremely challenging topic. The reviewer found that this project addresses such critical problems with well-designed approaches.

Reviewer 2:

Bottom-up design approaches were adopted to tackling the stability issue of a metallic Li anode. In the project, both an RPC and EAM were utilized to suppress the growth of Li dendrite. The advantage of these approaches is that the formation of the protective layer was driven by thermodynamics. However, the components used were electrochemically active or electronically conductive. The reviewer stated that the potential impact of residual electronic-conductive components is unknown.

Reviewer 3:

This work has demonstrated the effectiveness of the approach to use a polymeric ionomer to form an artificial SEI layer in combination with modified graphene oxide (GO). The team has designed and synthesized a new class of F- containing precursor polymers, which can convert into a Li-ion ionomer during the Li-deposition process. The GO is also used to provide additional adjustment to the properties of the artificial SEI layer.

Stabilizing Li-metal deposition is an important thrust to enable a Li-metal electrode. Designing an artificial SEI layer has been very actively pursued by many researchers in this field. The team has demonstrated through testing that their SEI layer design has significantly improved stability of Li-metal compared to the baseline system.

The reviewer remarked that the presentation needs to address two issues: the function of the GO materials and the interaction of the polymer with GO materials; and the mechanism of Li-ion transport in this composite layer.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Outstanding progress has been made toward the overall project. This project demonstrated two impressive accomplishments. First, it observed that thin RPC-derived SEI, distinct from conventional electrolyte-derived SEI, enables uniform Li deposition upon long cycling. Stable cycling (over 200 cycles) of a 4-V Li|NCM523 battery cell was achieved under lean electrolyte (7 microliters [µL]/mAh), limited Li excess (1.9-fold excess of Li), and high areal capacity (3.4 mAh/cm^2). The polymer-inorganic structure of the RPC-derived SEI confers good stability and effective suppression of electrolyte decomposition based on the NMR studies, and the results were published in *Nature Materials.*

Second, the electrochemically active EAM modification on Cu provided an LiF-rich inner phase and amorphous outer layer, which efficiently improve the cycling performance of Li-metal batteries at -15°C. At low temperature (-15°C), the Li@EAM Cu anodes demonstrate dramatically improved cycling performance, which is comparative to the performance at 25°C.

The reviewer saw these technical achievements and progress as outstanding against performance indicators.

Reviewer 2:
The team has made significant progress in the first year of the research. The team came up with a design of the polymer precursor and GO composite, synthesized the polymers, and put them into cell testing in a variety of different cell designs and chemistry. The team also reported excellent performance of the materials and cells tested. A variety of analysis techniques is used to understand the polymer-composite, artificial SEI layer before and after the deposition. The reviewer said that the team also came up with a convincing explanation of the function of the artificial SEI layer.

Reviewer 3:
The reviewer noted that outstanding interfacial stability was demonstrated.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The PI of this project, Professor Donghai Wang, has great collaboration with Dr. Alan Goliaszewski at Ashland Specialty Ingredients G.P. on the scale-up fabrication of the Li-ion conducting polymer; with Dr. Ji-Guang Zhang at PNNL on fabrication and testing of Li metal batteries; as well as with Dr. Anh Ngo on computational modeling from ANL. The reviewer saw the collaboration and coordination across the project team of this project as excellent.

Reviewer 2:
Excellent collaborative work with industry and National Laboratories. Each collaborator’s function is clearly defined.

Reviewer 3:
The team maintains a good collaboration with National Laboratories and an industrial partner.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
This project has effectively planned its future work and the milestones for the remaining time of this project; these are well thought out and a logical continuation of earlier milestones.

Reviewer 2:
The proposed future work is focused on understanding Li-nucleation and improving performance of the SEI layers. These are important directions for this project, according to the reviewer. The future work also provides numerical goals to accurately measure the performance enhancement.

Reviewer 3:
The team has a good plan for future work, mostly driven by the performance parameters. It will be of great interest to the reviewer to see how the team investigates the impact of the protective chemistry.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
According to the reviewer, this work greatly supports the development of high-energy-density battery technologies using Li metal.

Reviewer 2:
This project is very relevant to the DOE objective in the energy storage area to enabling high-energy-density batteries.

Reviewer 3:
The reviewer found this project to be highly relevant and supportive of DOE objectives to develop an affordable, high-energy-density battery for electric vehicles. There is still a challenge to achieve dendrite-free plating and stripping of Li with high-cycling efficiencies. This will be required to achieve long cycle life required for affordability. The effort is addressing this issue.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that the resources of this project are sufficient to achieve the milestones on time.

Reviewer 2:
Resources are sufficient to conduct the proposed task.

Reviewer 3:
Resources are sufficient for the work performed and planned.

Presentation Number: bat446
Presentation Title: Electrochemically Stable, High-Energy Density Lithium-Sulfur Batteries
Principal Investigator: Prashant Kumta (University of Pittsburgh)

Presenter

Prashant Kumta, University of Pittsburgh

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

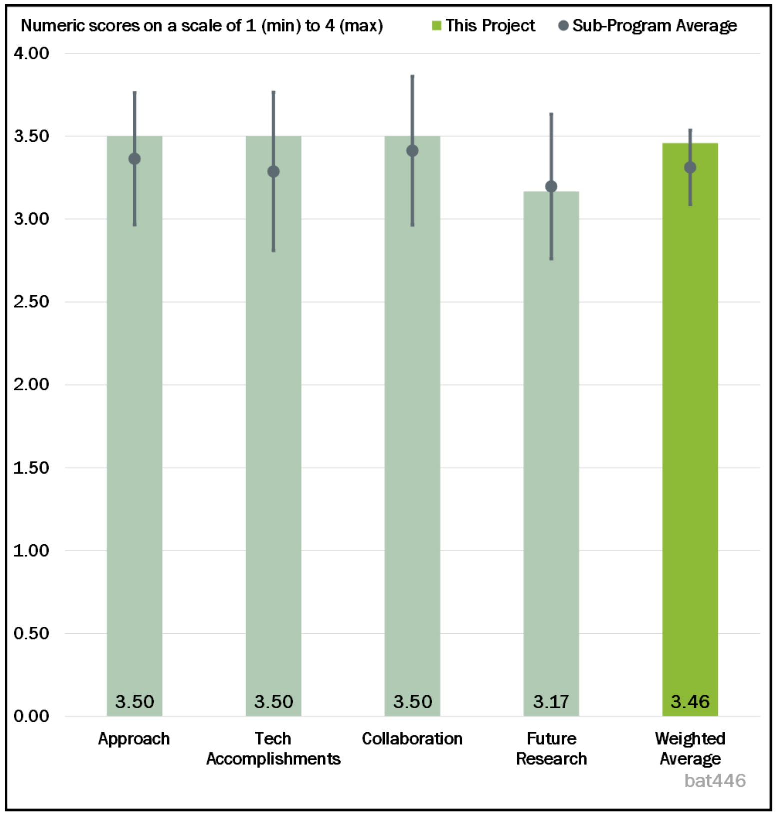

Figure 2-53 - Presentation Number: bat446 Presentation Title: Electrochemically Stable, High-Energy Density Lithium-Sulfur Batteries Principal Investigator: Prashant Kumta (University of Pittsburgh)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that this project is well designed with multiple approaches to overcome the technical barriers of low CE, limited cycle life, and poor rate capability of Li-S batteries:

- Generation of composite framework materials (CFM) enabling high-S loading and polysulfide (PS) confinement
- Interface engineering of CFM-S by homogeneous, non-porous, high electronic-conducting (EC) and Li-ion conducting (LIC) conjugated Li-polymer S- containing polymer (CLi-P-SCP) PS dissolution-resistant coatings to confine PS in order to improve the cycle life and rate capability
- Development of novel 3-D architecture electrode using EC- and LIC-coated CFM-S of targeted capacity (greater than 6 mAh/cm^2) using 3-D printing to achieve the desired architecture (control porosity and thickness).

This reviewer found that this project addresses such critical problems with well-designed approaches.

Reviewer 2:

The project developed multiple approaches to achieve a high-loading, high-S utilization, and longer cycle life Li-S battery. The reviewer found the approach of using a catalyst to rapidly convert polysulfide to lithium sulfide (Li_2S) to be very appealing. In the novel 3-D electrode, approach and high porosity are beneficial to the cycling performance and to achieve higher area loading. However, higher porosity could negatively impact the volumetric energy density of the battery.

Reviewer 3:
The project seemed well defined to the reviewer to address overcoming barriers to the technology. There is an approach presented to advance technology and efforts to address and overcome barriers.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
According to the reviewer, the team has made excellent progress in this review period.

On the materials front, the team developed complex framework materials and used lean electrolyte and Battery500 protocols to test the cells. On the interface front, the team developed electronic-conductor-coated and Li-ion conductor coated complex framework materials that showed improved performance. The team also performed 3-D printing to generate a high-S loading electrode and demonstrated improved cycling performance. The team also developed functional catalysts to convert polysulfide into Li_2S and leveraged computational capabilities to understand the mechanism.

Reviewer 2:
Some progress has been made toward the overall project. This project showed several technical accomplishments:

- XPS analysis shows that the content of polysulfides on the CFM separator was significantly lower than the commercial reference after multiple cycling.
- EC-coated CFM of nano-crystalline porous architecture shows the ability to trap PS and to improve the areal capacity.
- LIC-coated CFM of nano-crystalline porous architecture show an excellent ability to trap PS with improved areal capacity.

These achievements are significant. However, they are scattered in several research areas and lack a focused effort to reach the overall goals of this project. The reviewer sees that these technical achievements and progress are good against performance indicators.

Reviewer 3:
The project seemed to the reviewer to be on track toward the target milestones.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This is a truly collaborative effort including academia and industry. The academic collaborator is from the University of Pittsburgh; the industry collaborators are from Malvern Panalytical, Kurt J. Lesker Co. and Flex Cellz. Each collaborator's role is clearly defined.

Reviewer 2:
It seemed to the reviewer that a good team has been assembled to address the identified barriers to the technology.

Reviewer 3:
The PI of this project has good collaborations and coordination.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
According to the reviewer, there seem to be a solid plan and pathway to developing the test cells for DOE performance characterization.

Reviewer 2:
The project has effectively planned its future work in developing a high-loading electrode, fabricating pouch cells, and further developing a 3-D electrode. It is planned in a logical manner by incorporating appropriate targets of 6- mg/cm^2 loading and a 100-mAh cell. The team understands technology barriers to the realization of the proposed goals.

The proposed future work on high-S loading electrode and developing pouch cells is made up of all-important tasks. However, the reviewer commented that the strategy of a catalyst to facilitate conversion of polysulfide to Li_2S and Li_2S_2 is a very attractive approach to minimize polysulfide dissolution. More work needs to be performed in this topic.

Reviewer 3:
This project team has reasonably planned its future work, and the milestones for the remaining time of this project are somewhat well thought out and a logical continuation of earlier milestones. The reviewer asserted that the problem with the future plan is the lack of focused effort to achieve the overall goal of this project.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is relevant and supportive of DOE objectives to develop an affordable, high-energy-density battery for electric vehicles. There is still a challenge to achieve Li-S batteries with high CE, long cycle life, and good rate capability. The effort is trying to address such challenges.

Reviewer 2:
This project is very relevant to objectives of DOE in energy storage: high energy, long lifetime, low cost, and use of earth-abundant materials.

Reviewer 3:
Yes, this project supports the DOE objective of developing high Wh/kg battery technologies.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Research proposed seemed to the reviewer to be well matched with the allocated funds.

Reviewer 2:
The resources are sufficient to the work performed and planned.

Reviewer 3:
The reviewer found the resources of this project to be sufficient to achieve the milestones on time.

Presentation Number: bat447
Presentation Title: 3-D Printed, Low-Tortuosity Garnet Framework for Beyond 500 Wh/kg Batteries
Principal Investigator: Eric Wachsman (University of Maryland)

Presenter

Eric Wachsman, University of Maryland

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

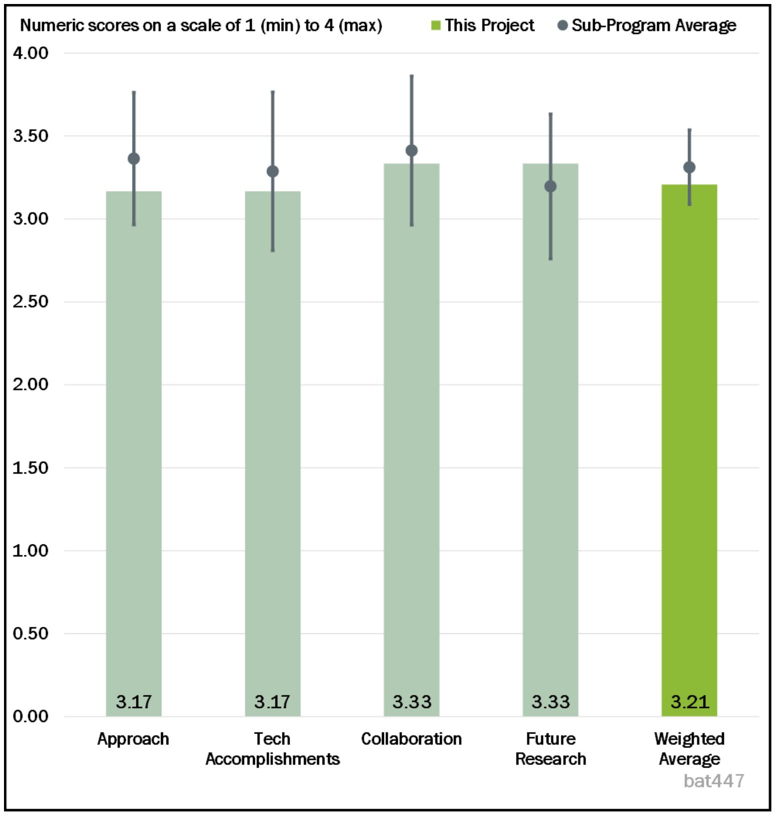

Figure 2-54 - Presentation Number: bat447 Presentation Title: 3-D Printed, Low-Tortuosity Garnet Framework for Beyond 500 Wh/kg Batteries Principal Investigator: Eric Wachsman (University of Maryland)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This work has demonstrated the effectiveness of using 3-D structures of garnet-type, solid-state, superionic Li-ion conductors in the electrode. The project has extended the 3-D structure in both the anode and cathode. The 3-D approach is realized with 3-D printing techniques. Due to the extended surface area, a 3-D based, solid-state electrode is a reasonable approach to achieve high energy density on the cathode side and to slow down Li-dendrite formation on the anode side. The reviewer remarked that 3-D printing is also a scalable approach for future manufacturing.

One aspect that the PIs need to consider is the brittleness of the garnet materials. The ceramic materials and 3-D structures lack flexibility for scaling up to a larger and multi-layer battery.

Reviewer 2:

This project is well designed with three approaches to overcome the technical barriers, such as low interfacial surface area for the thick electrode and poor rate capability for solid-state batteries:

- First, develop solid-state ionic and electronic-transport models to optimize the structure and experimentally validate models
- Second, develop 3-D printing techniques and fabricate high-porosity, low-tortuosity $Li_7La_3Zr_2O_{12}$ (LLZO)-garnet structures
- Third, fabricate and demonstrate high-energy-density, 3-D printed, solid-state batteries.

The reviewer found this project addresses such critical problems with well-designed approaches.

Reviewer 3:
Most of the approach looked fine to the reviewer. However, the PIs did not respond to the questions posed by the reviewers, thus making it very difficult to evaluate their work.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The PIs have made significant progress this year. A 3-D printing method was successfully used to make the 3-D electrodes of two different structures. The electrodes with 3-D structures demonstrated performance improvement in the testing cells. Modeling is successfully used to understand the current and field distribution to aid the 3-D structure design.

Electrodes with high loading of ~4 mAh/cm^2 of the cathode were fabricated and tested at 60°C at reasonable current density of 30 mA/g (~C/5).

Reviewer 2:
According to the reviewer, excellent progress has been made in the overall project. This project showed several technical accomplishments:

- Developed ink compositions to optimize rheology, as well as drying and sintering conditions to 3-D print multiple, low-tortuosity LLZO structures
- Achieved sintered approximately 200 μm LLZO column height on bilayer garnet structure
- Developed conformal coating of CNT inside garnet pores, which created a mixed electron-ion conducting framework to enable “Li-free” anodes
- Used a sputtered Cu-layer on the exterior surface of the porous LLZO layer to provide electrical contact for Li deposition as Li rises toward the dense layer during plating
- Fabricated and demonstrated full cells with a 3-D printed LLZO cathode.

These achievements are quite impressive for reaching the overall goals of this project. The reviewer saw these technical achievements and progress as excellent against performance indicators.

Reviewer 3:
The achievements are good; however, it was difficult to clarify several of them as the PIs were nonresponsive to the reviewers’ questions.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project seemed very well coordinated to the reviewer, and there is one collaborator.

Reviewer 2:
The PI of this project has very good collaborations.

Reviewer 3:
This is mainly a university project with professors at the University of Maryland.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer commented that the PIs showed an excellent plan for the final year of the project.

Reviewer 2:
The proposed future work is focused on the 300-Wh/kg and 500-Wh/kg battery fabrication and testing. These are important directions for this project, according to the reviewer. The future work also provided numerical goals to accurately measure the performance enhancement.

The PIs need to define clearly how the 300 Wh/kg and 500 Wh/kg are calculated. Is this a cell-level number including all components or just the cathode anode and electrolyte? What is the cell capacity, besides energy density?

Reviewer 3:
Future work for this project is well planned, and the milestones for the remaining time of this project are well thought out and a logical continuation of earlier milestones. According to the reviewer, a problem with the future plan is the lack of detailed approaches to achieve the overall goal of this project.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is relevant and supportive of DOE objectives to develop an affordable, high-energy-density battery for electric vehicles. There is still a challenge to achieve all solid-state batteries with long cycle life and good rate capability. This project is well designed to address such challenges.

Reviewer 2:
The reviewer found this project to be very relevant to DOE objectives in energy storage—a high-energy-density, safe, and long cycle-life battery.

Reviewer 3:
The plan stated in the Summary slide goes along with the objectives of the Battery500 program.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that resources are sufficient for the work performed and planned.

Reviewer 2:
The resources of this project are sufficient to achieve the milestones on time.

Reviewer 3:
The team seems to have the proper equipment, and visits to the team's laboratories corroborate this. However, the funding seemed somehow high to the reviewer.

Presentation Number: bat448
Presentation Title: Advanced Electrolyte Supporting 500 Wh/kg Lithium-Carbon/Nickel Manganese Cobalt (NMC) Batteries
Principal Investigator: Chunsheng Wang (University of Maryland)

Presenter

Chunsheng Wang, University of Maryland

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

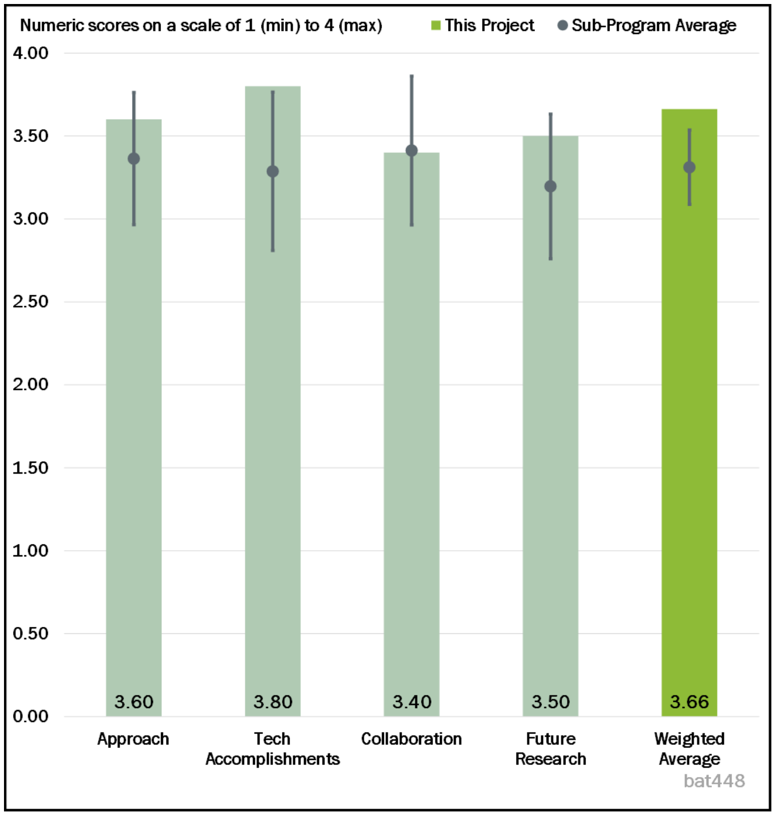

Figure 2-55 - Presentation Number: bat448 Presentation Title: Advanced Electrolyte Supporting 500 Wh/kg Lithium-Carbon/Nickel Manganese Cobalt (NMC) Batteries Principal Investigator: Chunsheng Wang (University of Maryland)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This team has done excellent work in developing novel electrolytes that can form lithiophobic LiF-rich SEI on a Li- anode surface and Li-rich CEI on a Ni-rich NMC cathode surface. Developing all fluorinated electrolyte and lithiophilic substrates has been demonstrated to be effective in overcoming barriers for a Li-metal anode, such as low CE, Li-dendrite formation, and unstable cyclic performance. At the same time, this approach is also appropriate and effective to protect the surface of Ni-rich cathode materials. This project is well designed and planned, and the approaches adopted here address the key barriers of Li-anode and Ni-rich cathode materials.

Reviewer 2:

As a seedling project for Battery500, the PI and team have exceeded the expectation through outstanding work. First, there is the electrolyte-development plan using high concentrated electrolytes and additives for carbonate-based systems. The compositional approach to develop electrolytes capable of wide-temperature cycling is important. The team has also developed a feasible approach for making lithiophilic and lithiophobic substrates for uniform Li stripping and plating.

Reviewer 3:

The reviewer commented that the combination of lithiophilic substrate and lithiophobic LiF SEI to enhance the CE of a Li anode is innovative. The effectiveness of the design principle has been demonstrated by the recorded CE of more than 99.8% for Li anodes (highest CE for Li anode is 99.5%) at a high current of 0.5 mA/cm^2 and 1.0 mAh/cm^2.

For high-capacity electrodes (Li and Si anodes and $LiNiO_2$ and NMC811 cathodes) with a large volume change, the general electrolyte-design principle is to form SEI and CEI, which have weak bonding with active materials. This is critical for the success of high-energy Li-NMC811 cells and Li-$LiNiO_2$ cells.

Reviewer 4:
The PI focuses on addressing the interphase issue facing high-energy-density systems. The PI used two specific approaches. One is based on the correlation between interphase chemistry and electrolyte composition. The PI used various salt, solvent, and additives to form a LiF-rich SEI, which is known to be good for electrochemical cycling. The other approach is designing an interphase with lithiophilic substrate and a lithiophobic SEI on the Li anode to achieve high CE. The reviewer stated that these approaches are in line with the state-of-the-art understanding of the interphase and supported by theoretical and diagnostic characterizations.

Reviewer 5:
The PI proposed an effective approach for a more stable electrolyte for high-voltage cathodes by using salts that promote LiF in SEI and CEI and by using more stable fluorinated solvents. The PI did not list barriers that needed to be overcome. Even though the topic was electrolyte-centric, the PI presented results on high-Ni cathodes. Thus, it was unclear to the reviewer what the focus of this effort is.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The PI’s team has achieved tremendous success in meeting the milestone goals. This can be seen from both the high- profile publications and the excellent cycling performance of cells of practical relevance. More specifically, the PI has provided long cycle data for a Li anode, Si anode, Ni-rich cathode, and Li-rich cathode, all of which were tested under high-loading conditions.

Reviewer 2:
The reviewer remarked that Li plating and stripping on a bismuth (Bi)-graphite (G) substrate in 2.0 M $LiPF_6$-mixTHF electrolytes achieved 99.8% of CE, higher than 99.5% recorded CE for Li anodes at the same condition. Ionic-liquid electrolytes enable anode-free Cu-NMC622 to achieve more than 140 cycles at a capacity of 1.0 mAh/cm^2 (without pressure), which has not been achieved before. All fluorinated electrolytes with a LiDFOB additive enable $LiNiO_2$ to achieve a capacity of more than 250 mAh/g and a cycle life greater than 600, which the reviewer found highly impressive.

Reviewer 3:
The PI made significant accomplishments in improving the cyclic stability of the Li anode and Ni-rich cathode materials. The project milestones have been completed according to the project plan. The Li-plating and -stripping CE of 99.8% and full-cell CE of 99.9% are quite encouraging. The combination of lithiophilic substrates with lithiophobic LiF-rich SEI is also very interesting. These research results were published in top journals, such as *Nature Energy*, *Nature Nanotechnology*, and *Chem*.

Reviewer 4:
Discharge profiles of NCA||Li cells using 1.28 M LiFSI-FEC/FEMC-D2 electrolyte at different temperatures (-85°C to 70°C) look very promising. The reviewer would like to know if this has been tested on NMC811 cathodes.

All milestones and deliverables are completed way beyond expectation. Fluorinated and ionic-liquid electrolytes show promise for thick NMC cathodes. The LiF fluoride SEI and CEI help to achieve high CE for thick NMC cathodes.

The Mg-doped $LiNiO_2$ show good stability with no Co and good cycle life. The reviewer wondered what the areal capacity is or what the loading is of the cathodes that were tested.

The lithiophilic-lithiophobic surface modification of graphite and on Li-metal are new ideas. Has the PI thought of how these can be scaled up beyond proof-of-principle?

Reviewer 5:
This is a very high data-density poster. A lot of results were presented on various electrolytes, various high Ni nickelates, and 3-D lithiophilic hosts to mitigate interface. These results attested to the innovativeness of the PI.

However, it was difficult for the reviewer to assess the effectiveness of this work since supporting information on the cell parameters (e.g., N/P ratio) and testing parameters (e.g., rates, cut-off voltages) was not provided. It seemed that most of the results were based on coin cells with a low loading of 1-2 mAh/cm^2.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This project demonstrated wide collaboration with industry (Navitas Systems on solid-state batteries and Saft America) on the electrode and cell fabrication, with National Laboratories (PNNL and ANL) on electrolyte design and theoretical calculation and BNL on S and NMC cathode characterization.

Reviewer 2:
The reviewer said that the PI has collaborated with the industry, National Laboratories, and universities. The scope of collaboration work is broad, including electrode and cell fabrication, electrolyte component synthesis, material characterization, and theoretical calculation.

Reviewer 3:
Regarding this criterion, the PI has collaborated with two companies, three National Laboratories, and two universities on electrolyte and electrode design and validation.

Reviewer 4:
This is a seedling project. The reviewer did not know how much collaboration there is supposed to be. In any case, the progress has been extraordinary.

Reviewer 5:
The reviewer asserted that the PI did not provide any team details in the poster.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer found the proposed future research to be relevant to the overall project target and on the basis of current progress. The evaluation of Li-NMC811 and Li-$LiNiO_2$ pouch cells (areal capacity greater than 4.0 mAh/cm^2) using the PI's advanced electrolyte system is urgently needed in the context of meeting the Battery500 goal.

Reviewer 2:
The technical barriers were identified, and migration methods were proposed in the future work.

Reviewer 3:
This project will focus on developing a Li-C composite anode and testing performance of Li-$LiNiO_2$ and Li-NMC811 pouch full cells using all fluorinated electrolytes.

Reviewer 4:
The PI did not provide the percentage of completion on the project. However, based on the feasibility data, the reviewer suggested that the PI should down-select from the various promising electrolytes and demonstrate performance in a pouch cell with parameters (e.g., loading, N/P ratio, rate, g/Ah electrolyte) commensurate with achieving the 500 Wh/kg goal.

Reviewer 5:
From the poster, it was not clear to the reviewer if the project is continuing or completed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer found the technical accomplishments of this project to be exemplary. Many of the approaches can be followed to achieve high stability and cycle-life LIBs with energy density greater than 400 Wh/kg.

Reviewer 2:
This project, as a Battery500 seedling program, studies materials relevant to the Battery500 program (Li anode, Ni-rich cathode, Li-S cathode) at a scale of practical significance (large loading amount or large areal capacity).

Reviewer 3:
This project mainly focuses on developing an advanced electrolyte to support 500 Wh/kg Li-C/NMC batteries. As part of the Battery500 program, the reviewer asserted that this project highly supports the overall DOE objectives.

Reviewer 4:
Yes, this project aims to overcome the critical challenges of Li-metal anodes and Ni-rich cathodes, which are closely related to DOE goals.

Reviewer 5:
The work on electrolytes, high-Ni nickelates, and 3-D lithiophilic hosts is relevant to the Battery500 program.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
According to the reviewer, the PI sufficiently achieved the stated milestones in a timely fashion using the resources for the project and collaborating with other partners, including companies and National Laboratories.

Reviewer 2:
The team and collaborators have strong capabilities and adequate resources for the proposed research.

Reviewer 3:
The resources for the project are sufficient to achieve the stated milestones in a timely fashion.

Reviewer 4:
The resources are adequate.

Reviewer 5:
The reviewer stated that no funding amount was provided.

Presentation Number: bat449
Presentation Title: Controlled Interfacial Phenomena for Extended Battery Life
Principal Investigator: Perla Balbuena (Texas A&M University)

Presenter

Perla Balbuena, Texas A&M University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

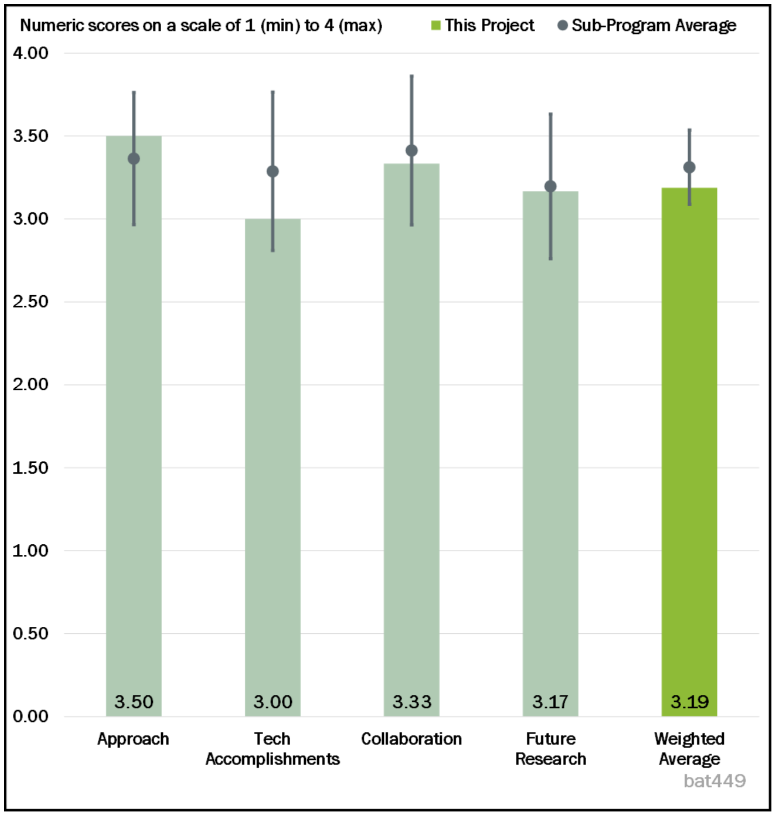

Figure 2-56 - Presentation Number: bat449 Presentation Title: Controlled Interfacial Phenomena for Extended Battery Life Principal Investigator: Perla Balbuena (Texas A&M University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Ab initio and classical molecular dynamics are powerful tools to investigate the structure and dynamics of electrolytes and the ion-transport mechanisms under an external electric field.

The reviewer said that collaboration with an experimental group at PNNL is important.

Reviewer 2:

The theoretical approach (e.g., ab initio and classical molecular dynamics) taken by the project team is very well designed to understand dilute, high-concentration, and localized high-concentration electrolyte decomposition at the electrode-electrolyte interface and the corresponding organic and inorganic structure of the SEI. The computational screening is expected to predict the optimum structure and formulation of novel electrolytes forming stable, uniform SEI with high Li-ion conductivity. Experimental synthesis and testing of theoretically predicted electrolytes in collaboration with PNNL will help to determine the validity of theoretical analysis and improve the theoretical model from experimental feedback.

The reviewer remarked that the system chosen by the project team is very appropriate for the current DOE project to solve the issue of performance degradation, such as uncontrolled growth of dendrites in Li-metal anodes and unstable SEI formation in Li-metal anodes and high-voltage cathodes.

Reviewer 3:

Application of density functional theory (DFT) simulations is expected to provide important details on reactivity in the concentrated and LHCEs and at the electrolyte-electrode interfaces. This is a suitable technique to complement experiments performed at PNNL; however, most of the presentation is dedicated to analysis of highest occupied molecular orbit (HOMO) and lowest unoccupied molecular orbit (LUMO) of solvent, salt, and diluent. The reviewer commented that this approach has been previously shown to produce erroneous predictions for battery electrolytes as discussed in "Electrochemical potential window of battery electrolytes: the HOMO–LUMO misconception". *Energy Environ. Sci.*, 2018,11, 2306-2309. Thus, most of the conclusions regarding reduction or oxidation of solvent, salt, or diluent are unreliable and likely do not correspond to the electrolyte reduction and oxidation at electrodes.

The micro-battery without an applied electric field shows very large deviation in the potential of bulk electrolyte that should lead to electrolyte decomposition that needs to be discussed and incorporated in a model.

Most of the motivation focuses on LHC electrolytes with TFEO diluent, but most of results are for bis(2,2,2-trifluoroethyl) ether with a 1,1,2,2-tetrafluoroethyl-2,2,3,3-tetrafluoropropyl ether (TTE) diluent. The reviewer stated that there is no conclusion regarding which diluent is better and why.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

According to the reviewer, the influence of an electric field (over-potential) on electrolyte reduction has been investigated and provided new and important insight into a reduction mechanism that has not been studied in this type of modeling before.

The HOMO-LUMO predictions of relative stability of electrolyte components were not correlated with experimental data and, according to previous work ("Electrochemical potential window of battery electrolytes: the HOMO–LUMO misconception". *Energy Environ. Sci.*, 2018,11, 2306-2309), do not provide realistic predictions of electrochemical stability of battery electrolytes. Simulations did not explain electrolyte stabilization.

For simulations of LHCE, the reviewer asked the project team to please compare predictions with experiments. No predictions of conductivity are given. It is important for the understanding of model accuracy.

Reviewer 2:

The modeling results can help explain the effectiveness of LHCE. But the reviewer found the modeling predictions to be rather incomplete. Specifically, the measurable properties of the SEI, such as the mechanical and transport (electronic and ionic) properties, are not modeled or predicted. As a result, it is difficult to compare modeling results with experiments.

Reviewer 3:

This theoretical study develops a detailed understanding of both structural and dynamic aspects of electrode-electrolyte interfaces in high-voltage cathode and Li-metal anodes using dilute, high concentration, and LHCEs. The Li-ion transport mechanism under an applied electric field has also been studied for LHCEs.

The PIs also carried out a preliminary investigation of SEI nucleation and growth, which can unravel the fundamental reaction pathways at the electrode-electrolyte interfaces of battery systems. This study will definitely help in designing new electrolytes and surface stabilization efforts of Li-metal anodes and high-voltage cathodes.

However, the reviewer asserted that no significant studies have been performed to understand the Li-ion diffusivity and migration within the organic and inorganic SEI layer, which are expected to be very important properties in understanding the dendrite formation of Li-metal anodes and performance degradation of high-voltage cathodes.

The PIs also mention the work in progress on machine learning and artificial intelligence (AI) for MD simulation, though no results have been presented.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The team at Texas A&M has an excellent collaboration in the National Laboratory (PNNL) network. The collaboration with the PNNL experimental group led by Dr. Jason Zhang, Dr. Jun Liu, and Dr. Jie Xiao on synthesis, testing, and prediction of SEI nucleation on Li metal will help to give feedback of experimental results on computational screening.

Reviewer 2:
There is good collaboration with PNNL with an experimental team providing electrolyte formulations and a modeling team providing HOMO-LUMO and electrolyte-structure predictions.

The reviewer asked the team to please show how modeling leads to new formulations that will be tested by PNNL and show improved properties.

Reviewer 3:
Collaborations with several researchers at PNNL should be enhanced by first modeling the mechanical and transport properties that can be measured and then experimentally testing key and specific predictions from the modeling effort, such as the SEI composition, mechanical, and transport properties.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The future efforts mainly focus on the further understanding of SEI nucleation and growth using impurities or defects as nucleation sites on Li-metal anodes. This study will be helpful in gaining a deep understanding of complex electrochemical processes occurring at the electrode-electrolyte interfaces. Future efforts to work with PNNL to establish clear connections between theory and modeling and electrolyte formulation could lead to the development of strategies mitigating the SEI formation. The future efforts for improved MD using machine learning and AI will definitely bring progress to the very demanding electrode-electrolyte interface modeling field.

Reviewer 2:
There is a good proposition to predict new formulations that will be experimentally tested; however, it was not clear to the reviewer how HOMO-LUMO calculations could be compared with characterization of SEI, CEI, and their properties.

Reviewer 3:
The reviewer asserted that the modeling effort should focus more on predicting the composition, structure, mechanical, and transport properties that can be experimentally measured. Close collaborations with experimentalists can also help specify and focus modeling activities. Specifically, the “defective sites” on “Li substrates” should be defined. “Effect of Li-metal thickness on battery performance” should be modeled by taking into consideration the mechanical behavior of electroplated Li and that of an externally applied pressure, as well as the SEI composition, structure, and mechanical and transport properties.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
According to the reviewer, the research project outcomes will lead to increasing the fundamental knowledge of electrode-electrolyte interface chemistry and the reactivity of Li-metal anodes and high-voltage cathodes using advanced modeling techniques. Experimental synthesis of the theoretically predicted electrolyte with controlled reactivity at the electrode-electrolyte interface may lead to Li-metal anodes and high-voltage cathodes for long cycle life and achieving the DOE targeted energy density without performance degradation.

Reviewer 2:
Modeling has a potential result in new electrolyte development ideas that will work with aggressive cathodes leading to improved energy density, if a correct modeling methodology is used.

Reviewer 3:
This reviewer observed high relevance.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources are adequate for the scope of the project.

Reviewer 2:
Sufficient resources are allocated.

Reviewer 3:
It was unclear to the reviewer how neural networks (NNs) are used since NNs are often treated as a black box that does not provide much insight.

Presentation Number: bat450
Presentation Title: Design, Processing, and Integration of Pouch-Format Cell for High-Energy Lithium-Sulfur Batteries
Principal Investigator: Mei Cai (General Motors)

Presenter

Mei Cai, General Motors

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

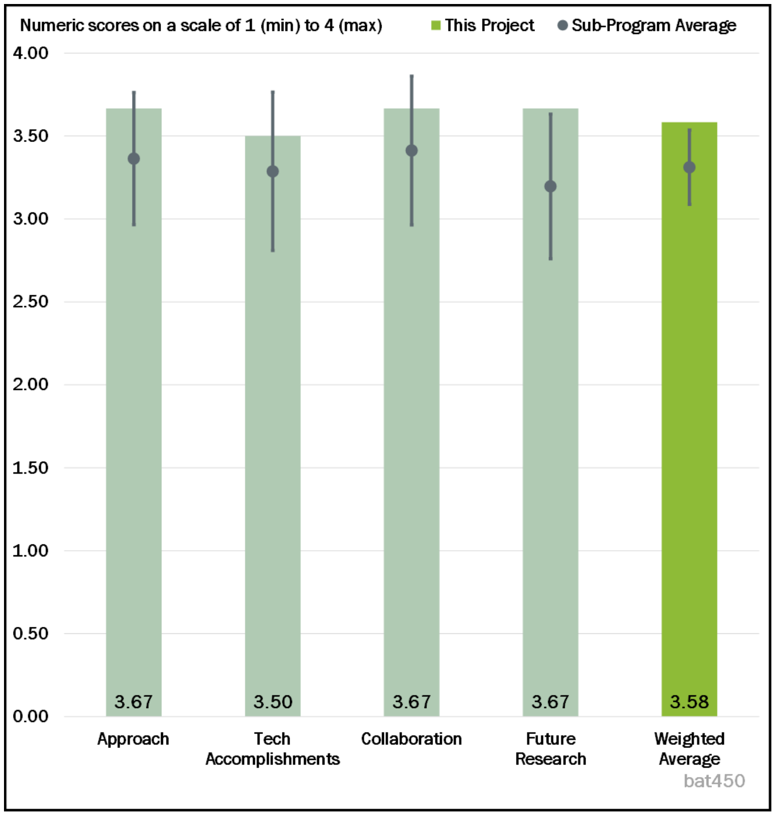

Figure 2-57 - Presentation Number: bat450 Presentation Title: Design, Processing, and Integration of Pouch-Format Cell for High-Energy Lithium-Sulfur Batteries Principal Investigator: Mei Cai (General Motors)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach of investigating binder, additives for better adhesions, surface protection of the Li-metal surface, and electrolyte optimization targets the most critical problems of the Li-S battery. Coupling with pouch-cell fabrication, testing and modeling can yield an excellent understanding of effectiveness of the approach. The overall approach of materials discovery and characterization along with reconditioned testing is comprehensive and outstanding for Li-S battery research. The reviewer asserted that not many institutions are able to provide such a comprehensive approach to the problems. The capabilities of coatings and scale-up are helpful not only to this project, but also will be useful for others to collaborate with GM and testing their Li-S battery innovations.

There are challenges of performing Li-S research along with Li-ion research as S compounds are interfering with Li-ion chemistry. It was useful to the reviewer to know how GM separates and leverages the two activities.

Scale-up materials production and pouch-cell testing of Li-S are important even at this early stage. The limited scale- up effort GM is undertaking is really important to pinpoint the issues of materials and systems.

Reviewer 2:

This team has done excellent work in optimizing the S cathode and electrolyte for high-energy Li-S pouch cells. Approaches adopted by this team—such as optimizing the porosity of the S cathode, introducing new dual-phase electrolytes as well as developing a polysulfide trapping layer on the separator—are effective and produced impressive results in improving the overall performance of Li-S cell.

Reviewer 3:
This project is well designed with three approaches to overcoming the technical barriers, such as low S-loading and cycling life, as well as the polysulfide shuttle issue for Li-S batteries. The first approach is for S-cathode optimization including screening of binder and additive for better adhesion, surface treatment for better interface contact, roll-to-roll scale-up of the slurry-coating process, and cathode-porosity control by optimization of calendar process. The second approach is electrolyte optimization through the development of new, dual-phase electrolytes. The third approach deals with pouch-format cell design, fabrication, and test protocol including implementation of a polysulfide-interlayer and cell design with an internally developed software tool. The reviewer found that this project addresses these critical problems with very well-designed approaches.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Excellent progress has been made toward the overall project. According to the reviewer, this project showed several technical accomplishments:

First, this project successfully designed and carried out a continuous S-electrode fabrication process using corona discharge for Al-surface treatment to improve the adhesion and a double-sided, flexible and rollable, crack-free electrode with high S-loading of 5 mg-S/cm^2.

Second, this project developed a polysulfide-trapping layer to improve cyclability of the S cathode, including the polypropylene (PP) separator coated with mixture of nano-oxide/C layer with a thickness of 10-16 µm and developed in-house a continuous coating process that can be easily scaled up for pouch-cell fabrication.

This reviewer saw these technical achievements and progress as outstanding against the performance indicators.

Reviewer 2:
The reviewer found the project progress to be excellent. In short period of time, the roll-to-roll (R2R) coater was built and tested. Scale up of S/C to kilogram scale was performed. The team also reported on the dual-phase electrolyte for Li-S battery. This is an interesting concept, and the reviewer would like to see more information and results related to this effort.

Reviewer 3:
The reviewer commented that this project has made remarkable progress in addressing the critical challenges of high-energy Li-S pouch cells. Coulombic efficiency and cyclic performance of Li-S cells were significantly improved by optimizing the S cathode and developing new, dual-phase electrolytes. Remaining challenges—such as further increasing the S loading, reducing the porosity of the cathode, and improving the Li-anode CE—are also identified in this project.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The PI of this project has excellent collaborations with the research groups led by Dr. Jun Liu and Dr. Jie Xiao at PNNL

Reviewer 2:
It is mainly a GM team with collaboration from PNNL. As this is a Battery500 seedling project led by PNNL, the collaboration is expected. PNNL has done quite a lot of the Li-S battery developments in the past. The collaboration helps to speed up the development process at GM.

Reviewer 3:
According to the reviewer, this project has a very good team and good collaborations with PNNL.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Future work plans are clearly identified, according to the reviewer. This project will focus on optimizing the cathode-fabrication process to improve S utilization as well as developing solid or liquid electrolytes to enhance cyclic stability.

Reviewer 2:
The reviewer remarked that this project has planned its future work well along with the milestones for the remaining time of this project.

Reviewer 3:
The proposed future work is focused on improving the R2R coating to increase loading and improving the electrolyte. These are important directions for this project.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Yes, this project aims to overcome the critical challenges of Li-S batteries, which are highly relevant to DOE goals.

Reviewer 2:
This project is very relevant to DOE's objective in energy storage: high energy, long lifetime, low cost, and using earth-abundant materials.

Reviewer 3:
This project is relevant and supportive of DOE objectives to develop an affordable, high-energy-density battery for electric vehicles. There is still a challenge to achieve Li-S batteries with long cycle life and good rate capability. The reviewer remarked that this project is well designed to address such challenges.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that resources are sufficient for the work performed and planned.

Reviewer 2:
Current resources for this project are sufficient to achieve the project goals.

Reviewer 3:
The resources of this project are sufficient to achieve the milestones on time.

Presentation Number: bat451
Presentation Title: Solvent-Free and Non-Sintered 500 Wh/kg All Solid-State Battery
Principal Investigator: Mike Wixom (Navitas Advanced Solutions Group)

Presenter

Binsong Li, Navitas Advanced Solutions Group

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

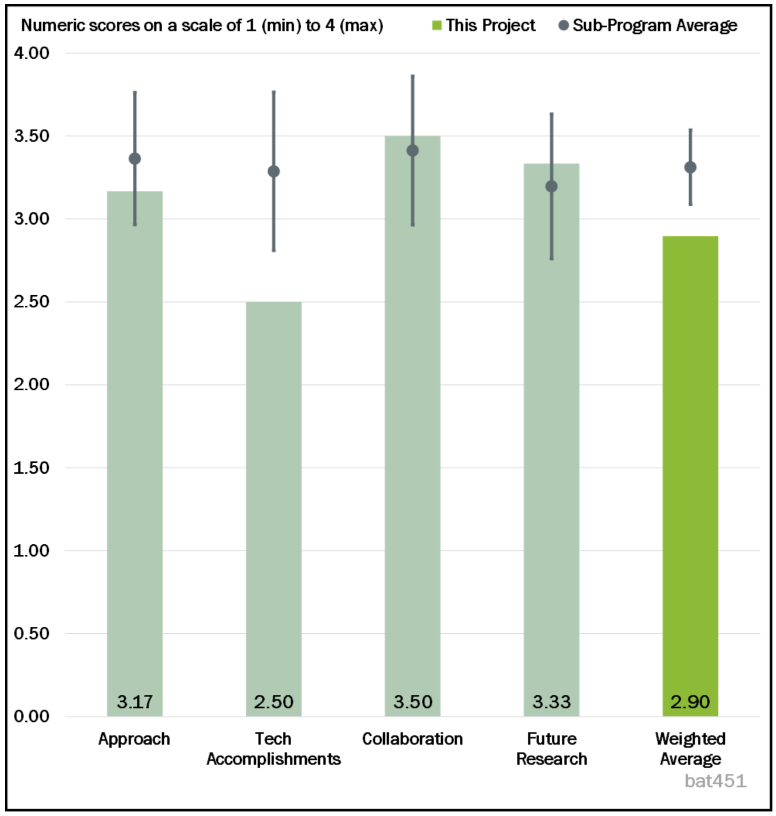

Figure 2-58 - Presentation Number: bat451 Presentation Title: Solvent-Free and Non-Sintered 500 Wh/kg All Solid-State Battery Principal Investigator: Mike Wixom (Navitas Advanced Solutions Group)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The team plans to tackle key issues associated with solid-state electrolyte (SSE) batteries from critical current density, cathode stabilization, and SSE stabilization to make them less air sensitive and prevent degradation for sufficiently long time needed for the roll-to-roll process, single-step lamination, and multi-layer stack assembly.

The reviewer indicated that the demonstrated air stability for 300 min. is an important achievement together with the initial stabilization of the lithium cobalt oxide (LCO) cathode, which increased capacity by almost a factor of two compared to an untreated electrolyte-electrode.

Testing of the currently assembled Li | treated SSE | treated NMC pouch cell will provide critical evaluation of the proposed approach. The reviewer remarked that preliminary results on the Li metal and Li |SSE | Li_2S indicate that it will be quite challenging to achieve 500 Wh/kg at room temperature for 1,000 cycles.

Reviewer 2:

The Li metal, S electrolytes, and high-energy cathodes are extremely relevant, but the reviewer was unconvinced that scaling up the manufacturing processes is relevant when Slide 6 shows a 25% capacity loss in three cycles.

Reviewer 3:
A summary of the Phase 1 effort would have been helpful to the reviewer for context in reviewing Phase 2, especially since the project has not been previously reviewed (per Slide 11 in version 2).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer stated that impressive progress has been reported toward stabilization of SSE in air and stabilization of the Li metal—SSE and treated LCO cathode—electrolyte interfaces via the interphase formation. It resulted in doubling of the LCO-cathode capacity and improved critical current densities for Li metal—electrolyte symmetric cells.

The best results are shown for the LCO cathode, while the most relevant to achieving 500 Wh/kg goals—NMC811 films with high loading—were prepared but have not been characterized. But it was not clear to the reviewer why electrolyte stability of NMC811 has been also achieved or not during cycling along with minimization of interfacial impedance for thick NMC811 **-** electrolyte. Results are lacking for the April milestone with 3 mAh/cm^2 loading of NMC811.

Reviewer 2:
This project has been operating for about 2 years and shows just three cycles of data on Slide 6. This seemed to the reviewer to be a very slow progress. No other progress, such as on stabilizing the Li-metal interface and enhancing the S-electrolyte air stability, is shown in any detail.

Reviewer 3:
Limited cell-cycle and performance data are shown to illustrate steps in development (i.e., Swagelok cell performance --> coin cell --> disk-in-pouch --> pouch). The reviewer understood that the focus has been on air stability and electrode-process development, but it would also have been helpful to see how these steps translate into performance, support, and understanding of technology potential along the pathway.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration between the University of Maryland, a National Laboratory, and Navitas seemed excellent to the reviewer with all parties contributing critical solutions for the problem.

Reviewer 2:
There was good communication among the collaborators and their contribution.

Reviewer 3:
The reviewer had no issues with collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer stated that the future work is excellent, and hopefully the team can execute on it.

Reviewer 2:
While the proposed plan is feasible, it was not clear to the reviewer what the team will do if the April 2020 milestone on cycling high-loading NMC811 cathode **-** Li metal shows fast degradation at room temperature. It is not clear what the mitigation strategy is for achieving 500 Wh/kg. The presented results for Li_2S | SSE | Li do not indicate that this approach will lead to 1,000 cycles with 500 Wh/kg at room temperature.

Reviewer 3:
Proposed research seemed appropriate to the reviewer, who requested cell-performance data to benchmark performance accomplishments in both developed processes and cell technology.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project addresses key technical barriers for mass production of the high-energy-density batteries with NMC811 and Li_2S cathodes and Li metal via materials and process development. If successful, these batteries have a potential to be used in transportation and energy storage applications.

Reviewer 2:
Yes, this project supports the DOE objectives to develop high Wh/g technologies.

Reviewer 3:
The Li-metal, S electrolytes, and high-energy cathodes are extremely relevant, but the reviewer was unconvinced that scaling up manufacturing processes is relevant when Slide 6 shows a 25% capacity loss in three cycles.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
It is a large project with a good combination of industrial, academic, and National Laboratory expertise, allowing the team to efficiently tackle challenging issues.

Reviewer 2:
Resources seemed sufficient to the reviewer to support the outlined research.

Reviewer 3:
There are appropriate resources for such an effort.

Presentation Number: bat452
Presentation Title: High-Energy Solid-State Lithium Batteries with Organic Cathode Materials
Principal Investigator: Yan Yao (University of Houston)

Presenter

Yan Yao, University of Houston

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

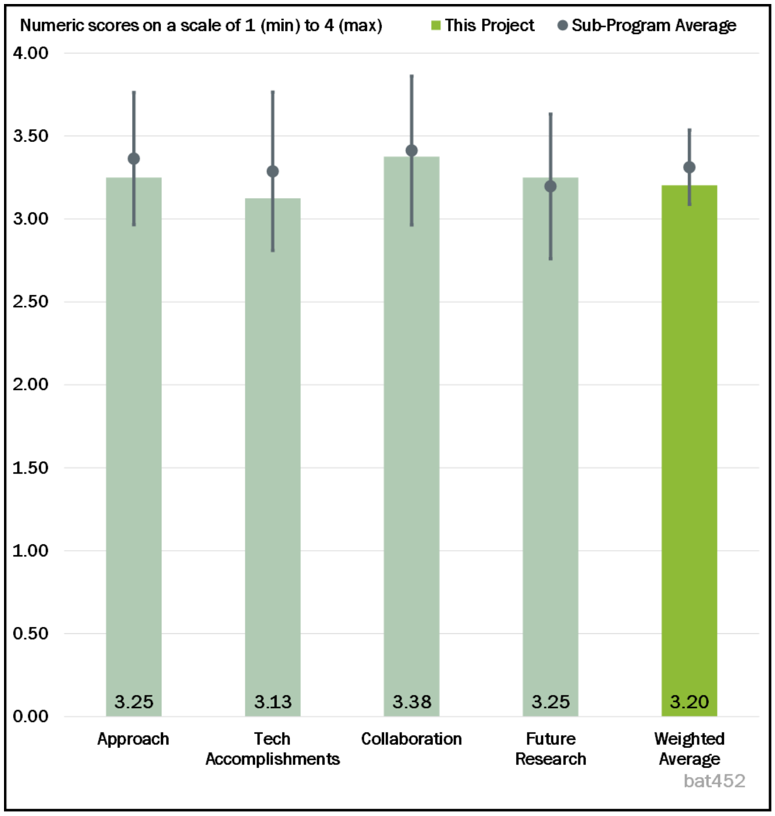

Figure 2-59 - Presentation Number: bat452 Presentation Title: High-Energy Solid-State Lithium Batteries with Organic Cathode Materials Principal Investigator: Yan Yao (University of Houston)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer found the approach used to investigate multi-electron, organic battery-electrode materials to be feasible and the plan is good. The focus this year has appropriately been on a major challenge confronting these types of systems—a low, active-material ratio (20 wt. %) in the cathode composition. The goal is to increase this to 60 wt. %. This will be necessary in order to meet the project-specific energy requirements.

Reviewer 2:

This project is well designed with approaches to overcome the technical barriers for solid-state Li batteries. This project designed a strategy of using a solution-assisted mixing method to form electrolyte-coated, organic insertion material (OIM), cathode-core shell structures that could be later compacted into an ideal microstructure. The reviewer found this project addresses the critical problems with well-designed approaches.

Reviewer 3:

The work certainly demonstrates the challenges faced by materials science in developing future battery materials.

Reviewer 4:

The PI proposed a solid-state battery technology by integrating multi-electron, OIMs, and sulfide-based solid electrolytes. According to the reviewer, the technical approach possesses high potential toward a low-cost, green, and high-energy battery technology. However, many significant barriers need to be addressed in future research: low theoretical capacity and voltage of organic cathodes, low-materials-utilization rate at high loading or high materials content, Li -instability for long-term cycling, and low cell-rate capability as a result of poor kinetics of both OIM materials and OIM/SEI.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Excellent progress has been made in the overall project, which the reviewer noted showed several technical accomplishments:

- This project successfully developed a solution process (SP) that drastically modified the microstructure, leading to homogeneous mixing of a pyrene-4,5,9,10-tetraone (PTO) cathode and a Li_6PS_5Cl solid electrolyte.
- Using the solution process, at 40 wt. % of active material ratio in the cathode composite, the material utilization increased from 49% (for the dry process) to 88% for the solution process.
- The improved material utilization is reflected at higher areal capacity, which is doubled compared to the dry process (at 40% PTO fraction).
- The cathode shows 75% retention for 100 cycles.
- An optimized solution process triples areal capacity to over 1.0 mAh/cm^2 and 87% capacity retention for 35 cycles.

These achievements are quite impressive for reaching the overall goals of this project. This reviewer saw these technical achievements and progress as excellent against performance indicators.

Reviewer 2:
The team made considerable progress toward improving the active material ratio and areal capacity by developing a solution-assisted mixing method this year. The team has already increased the active material ratio in the cathode composition from 20 wt. % to 40 wt. %. The reviewer commented that the study would benefit from a more in-depth analysis of the effect of discharge rate and shelf life on cell capacity.

Reviewer 3:
According to the reviewer, the project team achieved excellent technical accomplishments during this review period. The project team has been focusing on improving the active materials utilization rate and electrode areal capacity through the detailed studies of material improvement, cathode-electrolyte interface reactions, and effective materials processing. That technical progress also benefits other research in the battery community.

One thing that PI may evaluate is the relevance of the focused materials toward the final energy target. The PI may have a big picture in mind. The reviewer wanted to know what the possible pathways are toward the final performance targets and what the applicable materials are to fulfill such requirements.

Reviewer 4:
The project has accomplished much in terms of milestones. The project is on track and in good shape.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer said that the PI of this project has excellent collaborations with many research groups in this field.

Reviewer 2:
The project has very good collaboration. The team has been working well together and accomplished great things.

Reviewer 3:
The PI has close collaboration and coordination with universities and National Laboratory partners for materials development and characterization. The PI showed collaborative work on the polyimide membrane and cross-linked polymer electrolyte. The reviewer inquired if those membranes or electrolytes were adopted in the cell test.

Reviewer 4:
There is some collaboration with members of the Battery500 Consortium team members (PNNL and BNL). The reviewer suggested that the effort would be strengthened with greater interaction with other research institutions.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future plans are well focused. The team will continue to optimize the cathode-fabrication process to increase the active material ratio from 40 to 60 wt. %. Attempts will be made to increase rate capability by reducing the solid-electrolyte thickness.

Reviewer 2:
This project has planned its future work and milestones for the remaining time of this project well. However, the reviewer suggested that more technical details need to be developed for the future plan.

Reviewer 3:
The proposed future research is consistent; however, the reviewer remarked that the team needs more detail.

Reviewer 4:
According to the reviewer, the PI is aware of the significant challenges that still remain to get high energy and stable cycle life of the solid batteries and proposed reasonable future efforts. To reach or approach the target cell energy, new OIMs with higher capacity and voltage are essential and would be the focus of the future research. To tackle the sluggish kinetics of both the active materials and OIM/SEI, stable and highly conductive solid electrolytes should be identified to support the cell-level integration. Although Li-anode stability is a key to long-term cell cycling, it may be addressed through collaboration with other BMR teams and would not be the focus of the project.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewed noted that an all solid-state battery built on OIMs provides high potential for the next generation of low-cost and high-energy battery technology, which supports DOE's objective. Again, OIMs with higher capacity and voltage are the key to the success of the effort.

Reviewer 2:
The project is highly relevant to DOE's objectives and, if successful, would eliminate the use of Co that is predicted to have future supply constraints. A solid-state battery would minimize safety issues by eliminating flammable and volatile electrolytes.

Reviewer 3:
This project is relevant and supportive of DOE objectives to develop an affordable, high-energy-density battery for electric vehicles. The reviewer commented that there is still a challenge to achieve all solid-state batteries with long cycle life and good rate capability. This project is trying to address such challenges.

Reviewer 4:
This project is relevance to the DOE objective because the works develops improved materials and systems for high-energy batteries.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the project showed sufficient resources to achieve the stated milestones. The project team has accomplished good things with their resources.

Reviewer 2:
The resources appear to be adequate for completing the tasks within the time frame.

Reviewer 3:
According to the reviewer, the resources of this project are sufficient to achieve the milestones on time.

Reviewer 4:
The resources are appropriate for the scope of the project.

Presentation Number: bat453
Presentation Title: Composite Cathode Architectures Made by Freeze-Casting for All Solid-State Lithium Batteries
Principal Investigator: Marca Doeff (Lawrence Berkeley National Laboratory)

Presenter

Marca Doeff, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

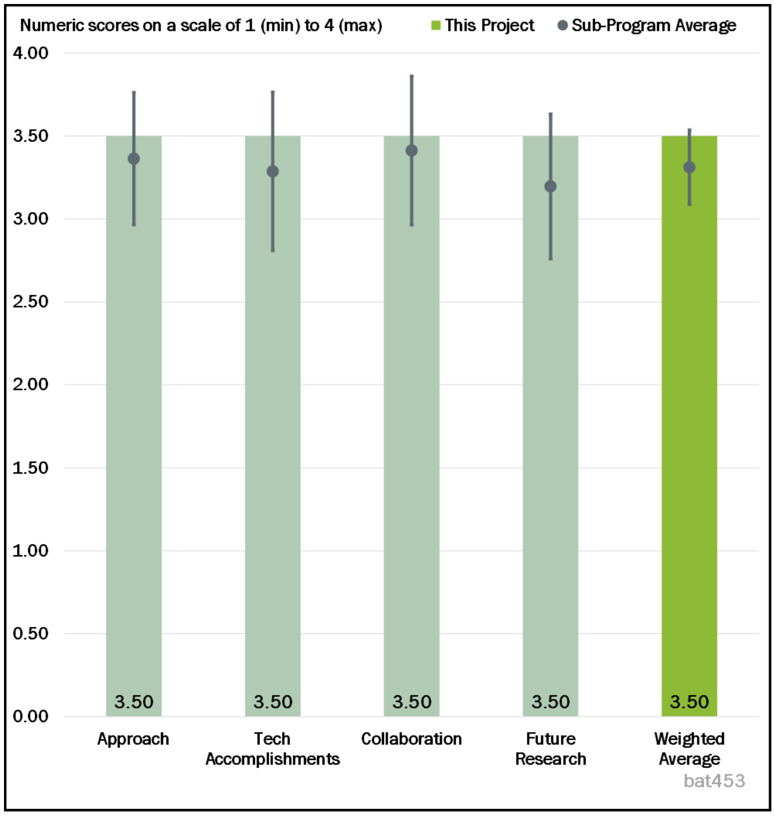

Figure 2-60 - Presentation Number: bat453 Presentation Title: Composite Cathode Architectures Made by Freeze-Casting for All Solid-State Lithium Batteries Principal Investigator: Marca Doeff

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, the PI and team have shown the feasibility of a full solid-state battery that can undergo cycling without a liquid electrolyte. The bi-layer and tri-layer garnet structure provides a scaffold for filling cathodes. Lower cell impedance occurs when a plastic solid electrolyte is filled in the pores of the LLZO-NMC cathode structure. The freeze-casting method can be optimized to maximize active material and performance. Combining the tape with the freeze-casting method provides an excellent approach overall toward fabrication of solid-state batteries.

Reviewer 2:

The approach for fabricating a porous electrode with connected channels using freeze-tape casting is very innovative for solid-state LLZO Li batteries. However, the reviewer stated that how to reduce the interface resistance between LLZO and the cathode active materials, especially after cycles, still needs to be addressed.

Reviewer 3:

The research approach seems well designed to understand cathode properties to enable the construction of a high- energy-density battery.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
According to the reviewer, the team communicated a clear path for addressing and developing an understanding of the challenges around the LLZO framework to enable high energy-density cells.

Reviewer 2:
There is good control of density and thickness using the tape-cast method for producing thin LLZO structures. Porosity of LLZO layers can be varied using freeze-cast methods. The PI has developed a slurry method for incorporating NMC in the porous LLZO layer. The reviewer wondered about the filling fraction of the cathode either by weight or volume percentage. Overall energy density will be affected by the porous LLZO template. What was the weight fraction of the active cathode material versus the tri-layer template? Significant reduction of cell impedance occurred after incorporating plastic electrolyte—from 180 ohm/cm^2 to 350 ohm/cm^2. The reviewer wondered about the composition of the soft electrolyte.

Reviewer 3:
A porous LLZO layer with controlled pores was fabricated on a dense LLZO layer. The reviewer noted that it is still hard to fill all the pores with solid active materials. The contact between LLZO and active materials are hard to maintain during cycles. The cycle life and energy density of the cell need to be addressed. The three-layer structure cells are more suitable for liquid electrodes.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This is a collaborative project with Montana State University and Mercedes Benz.

Reviewer 2:
Dr. Doeff's team has collaborated with Montana State University and Mercedes Benz R&D North America.

Reviewer 3:
The reviewer remarked that the team expertise is clearly articulated and contributes to the research.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed research pathway seemed to the reviewer to be targeted toward the ultimate goal of a solid-state cell build.

Reviewer 2:
Optimization of the pore size and cathode particle size can increase the overall loading. The reviewer wondered if a theory and modeling effort can help to determine the pore size, geometry, and volume fraction of the active material, etc.

Reviewer 3:
The team proposed to develop methods to fill most of the LLZO-scaffold pore space. The reviewer commented that how to maintain the good contact between the LLZO scaffold and solid active materials during cycles is still a challenge.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer stated that the project supports the Battery500 goal toward achieving 500 Wh/kg. The tasks support stabilizing the Li-metal and cathode architectures using the porous framework.

Reviewer 2:
The project fully supports the overall DOE objective of developing high-energy, low-cost, and safe batteries.

Reviewer 3:
Yes, this project advances technology toward high energy-density battery technologies.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
LBNL has sufficient resources for the project to achieve the goal and milestones.

Reviewer 2:
Funding level seemed adequate to the reviewer for the planned research.

Reviewer 3:
Resources are adequate.

Presentation Number: bat454
Presentation Title: Development of Long-Life Lithium/Sulfur-Containing Polyacrylonitrile Cells
Principal Investigator: Ping Liu (University of California at San Diego)

Presenter

Ping Liu, University of California at San Diego

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

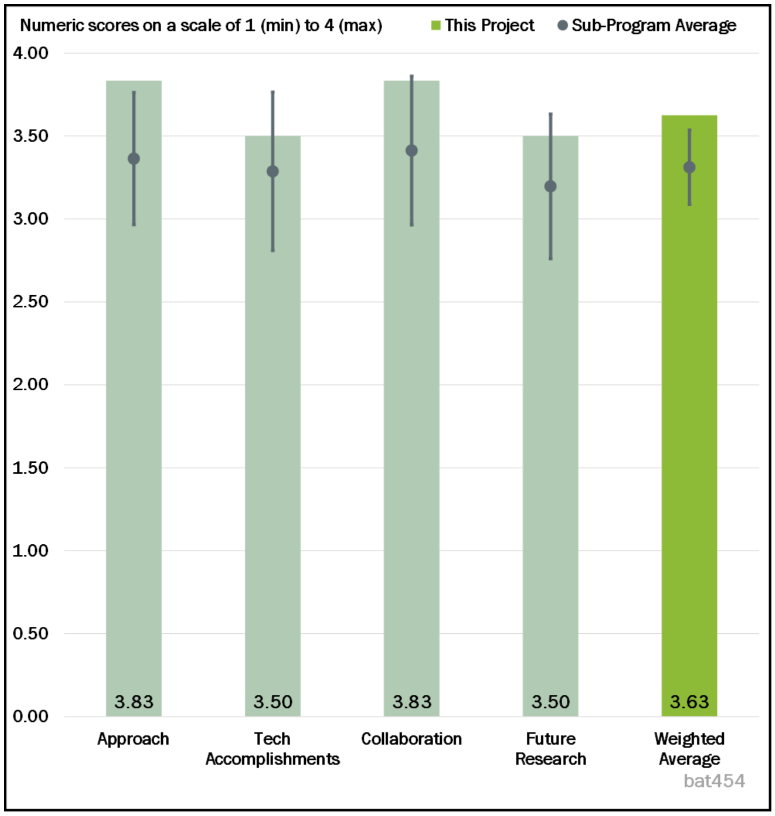

Figure 2-61 - Presentation Number: bat454 Presentation Title: Development of Long-Life Lithium/Sulfur-Containing Polyacrylonitrile Cells Principal Investigator: Ping Liu (University of California at San Diego)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This is a Keystone 2 project of the Battery500 Consortium focusing on electrode architecture of both anode and cathode. At the anode side, the work performed includes Li-metal protections and 3-D anode structures. Both approaches are focused on stabilizing the Li-metal surface and achieving uniform Li deposition. Several PIs of various institutions are part of this Keystone 2 project and have made significant progress. The anode work is highlighted in this presentation but is not discussed in detail.

The cathode work is focused on S and polymer-composite materials. In particular, sulfur and polyacrylonitrile are co-sintered to form a S-rich composite material. This composite can be potentially electronically conductive when doped to overcome the low electric conductivity of S materials. Elemental S is also covalently bonded with the carbon network to anchor the S to the cathode network structure to prevent polysulfide dissolution. The sulfurized polyacrylonitrile (SPAN) composite is a very effective approach to overcome the issues of the S electrode. Although this and similar approaches have been reported in the literature over the years, a systemic study has never been done to fully understand and quantify the approach. The current experimental work in combination with theoretical modeling is excellent to move the technology forward.

Another overlooked area in Li-S battery research is the Li-metal electrode and compatible electrolyte with both SPAN and Li metal.

Reviewer 2:
The approach of the research supported the overall Battery500 goals. SPAN and NCM811 with metallic Li could achieve the program goals. It appeared to the reviewer that the shuttle effect was reduced.

Reviewer 3:
The approach, such as the focus on S cathodes, is very good as the reviewer indicated like the NMC811 and higher Ni cathode R&D is reaching diminishing returns.

Regarding Slide 8, the reviewer stated that this was basically Seeo's construction, and the company found dendrite issues eventually.

Regarding Slide 4, the reviewer said that the 2 V, open-circuit voltage (OCV) of the S couple makes high energy challenging. This project's goal of 300-350 Wh/kg looked concerning to the reviewer, considering where the Li metal/NMC cell currently is. Hopefully, there is a clear path to reaching 500 Wh/kg.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The team made significant progress on Li-metal protection and 3-D Li deposition. Multiple methods of Li-metal protection are developed within the team, such as polymer-based surface protection, solid-state electrolyte, and electrode additives. These approaches have generated high efficiency and long cycle life for Li-metal deposition during testing in their own institutions. At the S cathode side, the team has developed a Li-metal, compatible electrolyte system for the SPAN cathode. This is an outstanding solution to a long-existing problem for the SPAN- based Li-sulfur battery.

Reviewer 2:
The progress of the project meets the program expectations and all the milestones were achieved.

The reviewer had a question and a comment:

During the discharge of SPAN, does any S become dissolved?

The rate of the cells in the new electrolyte with SPAN should be described next time.

Reviewer 3:
Again, Slide 10 shows 99.37% CE, which means that twice the amount of Li is gone in 150 cycles. Subsequently, this needs to be increased substantially. The reviewer indicated that it should not be necessary to cycle a cell 900 times to determine that the CE is too low to be commercially viable.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This is an outstanding team with a prominent scientist, such as Goodenough; a strong team lead, Liu; and both established and fledging scientists. The team includes both experimental and theoretical (Texas A&M) aspects of the work with strong testing and diagnostics efforts (BNL).

Reviewer 2:
The reviewer found the collaboration and coordination across the project team to be nicely integrated.

Reviewer 3:
The PI demonstrated the collaboration across Battery500 teams.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer noted that the team has proposed several different fronts for future work. This is well justified since multiple PIs will be involved in the Keystone 2 project.

Understanding 3-D electrodes in a pouch cell is important as the new approaches need to be verified in a realistic setting. Performing simple-system modeling before the pouch cell work can provide a better understanding of the approaches. In fact, most of the Li-metal protecting work and approaches will need to be tested in a standard cell setting and in a more controlled and comparable environment. The simple-system modeling in Slide 17 is a particularly good approach that compares different compositions and chemistries. This really shows the advantages and limitation of SPAN and where the S electrode research needs to be focused.

Reviewer 2:
The PI provided the high-level description of the future work. This is logical to achieve the overall program goals.

The reviewer stressed that the PI should provide more details so the barriers to the realization can be better accessed.

Reviewer 3:
The S cathode work is more than difficult enough; the reviewer would not have this team worried about 3-D Li anodes (see Slide 18).

This comment is not directed at Professor Liu, but the reviewer thought that the Battery500 program would benefit from additional cathode R&D beyond or instead of the high Ni NMC. That work is likely reaching diminishing returns, and S is extremely difficult (but very worth pursuing).

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The Keystone 2 project is geared well with the DOE-VTO objectives of developing high energy-density and long cycle- life batteries. Li-metal anodes have promise to enable very high-energy-density rechargeable batteries. The key challenges are Li dendrites and un-uniform deposition. A major part of the work is focusing on addressing both issues and is making outstanding progress. The SPAN electrode work is particularly supportive of DOE's mission to use earth-abundant materials for large-scale energy storage deployment. The SPAN materials only contain S, C and N, making it a very attractive materials for large-scale deployment.

The reviewer observed that one has to put this progress into prospective and understand that Li dendrites and S electrodes have been very challenging issues for the science community for the past half a century.

Reviewer 2:
Research on S or NMC811 cathode and metallic Li anode is definitely relevant to DOE goals.

Reviewer 3:
The reviewer said that this project is highly relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that there are appropriate resources.

Reviewer 2:
The team seems to have sufficient resources for the work reported. However, it was hard for the reviewer to judge. There is only a lump sum amount of funding for the entire Battery500 project in the Overview slide. It is not clear how much support there is for each sub-team and task.

Reviewer 3:
The PI has adequate resources for the proposed research.

Presentation Number: bat455
Presentation Title: In Operando Characterization of Lithium Plating and Stripping
Principal Investigator: William Chueh (Stanford University)

Presenter

William Chueh, Stanford University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

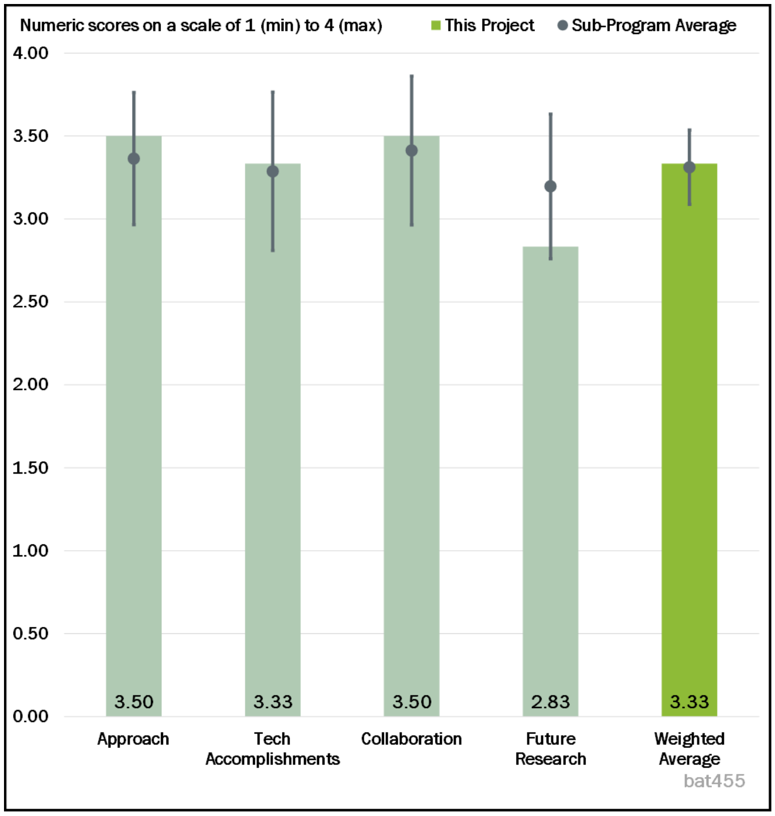

Figure 2-62 - Presentation Number: bat455 Presentation Title: In Operando Characterization of Lithium Plating and Stripping Principal Investigator: William Chueh (Stanford University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project aims to develop operando diagnostics tools to monitor Li plating and stripping and provide guidance on electrolytes, additives, and cycling procedures for developing Li-metal based batteries. The reviewer indicated that this is an excellent approach that directly addresses the need to achieve the overall goals in the Battery500 program.

Reviewer 2:

The approach of this project is to develop in situ spectroscopic techniques to understand morphology evolution and CE trends in Li-metal stripping and plating in liquid electrolytes. A few key questions are clearly outlined, and the techniques developed are used to answer them.

Reviewer 3:

The main challenge of the Battery500 project is the stability of the Li-metal electrode. This project strives to quantify the Li electrode during operation.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The milestones are completed or on track. There were numerous presentations given by the PIs although no publications yet (the reviewer imagined that a few are on the way in FY 2020 given the well-developed nature of the data sets presented).

The in situ XRD work is very nice and clearly shows the reactivity problem of Li-metal in carbonate solvents. The reviewer was surprised at how important open-circuit corrosion of Li is in this solvent system and was pleased with the clarity about how these results show this to be a problem. The addition of HF to manipulate the Li- metal deposition morphology is also a nice outcome. Grazing-incidence small angle X-ray scattering (GISAXS) and atomic force microscopy (AFM) are currently being developed to further understand the morphology and nucleation during Li-metal plating.

Reviewer 2:
The reviewer stated that very good progress was made in this project. Studies using three operandi diagnostics tools were presented: XRD, GISAXS, and AFM.

Operando XRD was used to quantitatively probe Li plating and stripping and track the amount of Li on the surface. Because XRD of Li (110) was used as the sole marker, the detection limit as well as the accuracy and sensitivity of this technique should be considered. Li plating in real battery cells is known to take various forms and crystalline orientations, which may present challenges in using this technique.

GISAXS was used to monitor periodic structure during Li deposition. While the study on an electrolyte pseudo-model system involving HF is very interesting, the reviewer wondered whether this may be system specific. How applicable is this technique to the real systems outside of the model?

Reviewer 3:
Quantifying Li deposition with X-rays is a challenge. This effort seems to make these measurements about as well as the reviewer had seen. Information on morphology and microstructure is also supplied. Another study in this program suggests that some deposited Li can be non-crystalline. This is not accounted for in this study. Nevertheless, the presentation was informative.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration across the team in the Battery500 program is excellent. There was also a good use of the DOE user facilities.

Reviewer 2:
The reviewer was impressed with all Battery500 collaborations, including this one although not too much presented outside the two PI’s National Laboratories. There is still a strong collaboration between the two.

Reviewer 3:
Some collaboration is listed, but close collaboration is not apparent. The studies seem fairly independent.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Overall, the proposed future work is logical toward addressing the barriers in Li-metal based batteries.

Considering that Li plating and striping in a liquid electrolyte have been studied for decades, it would be useful to build and examine additional model systems based on the knowledge existing in the literature. The reviewer would also like to have seen some demonstration on using the techniques in real battery cells under realistic cycling conditions. In the end, it will be important for such diagnostic studies performed on cells over a large number of cycles.

Reviewer 2:
Proposed future work is a reasonable extension of current work although only briefly mentioned.

Reviewer 3:
The reviewer observed that continuing the present effort is proposed, with few details. No possible solutions are proposed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The use of a Li-metal anode is an important step toward achieving the Battery500 goals. Current technology faces significant challenges in terms of low CE of Li plating and striping. This project supports the overall DOE objectives, and it is very relevant.

Reviewer 2:
The reviewer commented that the PI attacks the main challenge for the program. If successful, this would reduce the cost of batteries.

Reviewer 3:
Enabling Li-metal electrodes is a key goal for DOE-VTO, and this project entirely aligns with that mission.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
It was unclear to the reviewer how much funding this project received, so it was difficult to judge whether or not enough resources are available. However, the overall Battery500 program has sufficient resources.

Reviewer 2:
The PI seems to have sufficient funds to conduct the studies.

Reviewer 3:
The project appears sufficiently supported although the total direct funding from the Battery500 to this project is not provided.

Acronyms and Abbreviations

°C	Degrees Celsius
µL	Microliter
3-D	Three-dimensional
AFM	Atomic force microscopy
Ah	Ampere-hour (amp-hour)
AI	Artificial intelligence
Al	Aluminum
Al_2O_3	Aluminum oxide (alumina)
ALD	Atomic-layer deposition
ALS	Advanced Light Source
ANL	Argonne National Laboratory
Bi	Bismuth
BMR	Battery Materials Research Program
BNL	Brookhaven National Laboratory
C	Carbon
CAM	Cathode active material
CB	Cell build
CC	Constant current
CEI	Cathode-electrolyte interphase
CE	Coulombic efficiency
CFM	Composite framework materials
CLi-P-SCP	Conjugated Li-polymer S- containing polymer
cm	Centimeter
CNT	Carbon nanotube
Co	Cobalt
CO_2	Carbon dioxide
COTS	Commercial off-the-shelf
CT	Computerized tomography

DCIR	Direct current internal resistance
DCR	Discharge capacity rate
DEMS	Differential electrochemical mass spectroscopy
DOE	Department of Energy
DRX	Cation-disordered rock salt
DST	Dynamic stress test
EAM	Electrochemically active monolayer
EC	Electrochemical (electronic) conducting
EDS	Energy-dispersive X-ray spectroscopy
EELS	Electron energy loss spectroscopy
EERE	Energy Efficiency and Renewable Energy
EIS	Electrochemical impedance spectroscopy
EM	Electron microscopy
EOL	End of life
ETEM	Environmental transmission electron microscopy
FC	Fast charge
FCE	First-cycle efficiency
FEC	Fluoroethylene carbonate
FSP	Flame-spray pyrolysis
FTIR	Fourier-transform infrared
FY	Fiscal Year
g	Gram
GISAXS	Grazing incidence small-angle X-ray scattering
GM	General Motors
Go	Graphene oxide
H	Hydrogen
HF	Hydrofluoric acid
HOLE	Highly ordered laser-patterned electrode

HOMO	Highest occupied molecular orbit
IC	Internal combustion
ICL	Irreversible capacity loss
INL	Idaho National Laboratory
IP	Intellectual property
JES	*Journal of the Electrochemical Society*
kg	Kilogram
LATP	Lithium aluminum titanium phosphate
LBNL	Lawrence Berkeley National Laboratory
LCO	Lithium cobalt oxide ($LiCoO_2$)
LFP	Lithium-ion phosphate
LHCE	Localized high-concentration electrolyte
Li	Lithium
Li_2S	Lithium sulfide
LIB	Lithium-ion battery
$LiBO_2$	Lithium borate
LIC	Lithium-ion conducting
LiDFOB	Lithium diofluoro(oxalate) borate
LiEDC	Lithium ethylene dicarbonate
LiF	Lithium fluoride
LiFSI	Lithium bis(fluorosulfonyl)imide
LiPAA	Lithium polyacrylate
$LiPF_6$	Lithium hexafluorophosphate
LiTFSI	Lithium bis(trifluoromethanesulfonyl)imide
LLS	Layered-layered spinel
LLZO	Lithium lanthanum zirconate
LMB	Lithium-metal battery
LMNO	Lithium manganese nickel oxide

LMNOF	Li-Mn-Ni-O-F
LMR	Lithium-manganese rich
LNCO	Lithium nickel cobalt oxide
LNMO	$LiNi_{0.5}Mn_{1.5}O_2$
LNO	Lithium-nickel dioxide ($LiNiO_2$)
LT	Low temperature
LTMO	Lithium transition metal oxide
LTO	Lithium titanate
LUMO	Lowest unoccupied molecular orbit
M	Molarity
MA	Methyl acetate
mAh	Milliamp-hour
MD	Molecular dynamics
MERF	Materials Engineering Research Facility
min.	Minute
MLPC	Multi-layer pouch cell
Mn	Manganese
$MnCO_3$	Manganese carbonate
mV	Millivolt
N/P	Negative-positive ratio
Nb	Niobium
NCA	Nickel cobalt aluminum oxide
NCE	No-cost extension
NCM	Nickel cobalt manganese oxide
NFA	Nanostructured ferritic alloy
Ni	Nickel
NMA	Nickel manganese aluminum
NMC	Nickel manganese cobalt oxide

NMCA	Nickel manganese cobalt aluminum
NMP	N-methyl-2-pyrrolidone
NMR	Nuclear magnetic resonance
NN	Neural network
NREL	National Renewable Energy Laboratory
OEM	Original equipment manufacturer
OEMS	Online electrochemical mass spectroscopy
OIM	Organic insertion material
ORNL	Oak Ridge National Laboratory
PDF	Pair-distribution function
PEO	Polyethylene oxide
PI	Principal investigator
PNNL	Pacific Northwest National Laboratory
PP	Polypropylene
PS	Polysulfide
PSD	Pore-size distribution
PTO	Pyrene-4,5,9,10-tetraone
PV	Photovoltaics
PVDF	Polyvinylidene difluoride
Q	Quarter
R&D	Research and development
R2R	Roll-to-roll
RPC	Reactive-polymer composite
RST	Reactive-spray technology
S	Sulfur
SAW	Surface-acoustic wave
SEI	Silicon electrolyte interface
SEI	Solid electrolyte interphase

SEISTA	Silicon electrolyte interface stability
SEM	Scanning electron microscopy
SERS	Surface-enhanced Raman spectroscopy
SiO_x	Silicon Oxides
SLAC	Stanford Linear Accelerator Center
Sn	Tin
SNL	Sandia National Laboratories
SOA	State of the art
SOC	State of charge
SP	Solution process
SPAN	Sulfurized polyacrylonitrile
SSE	Solid-state electrolyte
STEM	Scanning transmission electron microscopy
TEM	Transmission electron microscopy
Ti	Titanium
TM	Transition metal
TNO	Titanium niobium oxide
TTE	1,1,2,2-tetrafluoroethyl-2,2,3,3-tetrafluoropropyl ether
UCSB	University of California at Santa Barbara
UMEI	University of Michigan Energy Institute
URI	University of Rhode Island
UT-Austin	University of Texas at Austin
V	Volt
VTO	Vehicle Technologies Office
Wh/kg	Watt-hour per kilogram
wt. %	Weight percent
XFC	Extreme fast charging
XPS	X-ray photoelectron spectroscopy

XRD	X-ray diffraction

3. Energy Efficient Mobility Systems

The Vehicle Technologies Office (VTO) has a comprehensive portfolio of early-stage research to enable industry to accelerate the development and widespread use of a variety of promising sustainable transportation technologies. The research pathways focus on fuel diversification, vehicle efficiency, energy storage, and mobility energy productivity that can improve the overall energy efficiency and efficacy of the transportation or mobility system. VTO leverages the unique capabilities and world-class expertise of the National Laboratory system to develop innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures; and energy efficient mobility systems. VTO is uniquely positioned to address early-stage challenges due to strategic public-private research partnerships with industry (e.g., U.S. DRIVE, 21st Century Truck Partnership) that leverage relevant expertise. These partnerships prevent duplication of effort, focus DOE research on critical research and development (R&D) barriers, and accelerate progress. VTO focuses on research that industry does not have the technical capability to undertake on its own, usually due to a high degree of scientific or technical uncertainty, or that is too far from market realization to merit industry resources.

The Energy Efficient Mobility Systems (EEMS) subprogram supports early-stage research to support industry innovation that improves the affordability and energy productivity of the overall transportation system. Initial DOE analysis indicates that the future energy impact of connected and automated vehicles is highly uncertain and may be quite large, ranging from a potential 60% reduction in overall transportation energy use to a 200% increase in energy consumption. EEMS applies complex modeling and simulation expertise, experience with data science and artificial intelligence, and high performance computing (HPC) capabilities unique to DOE National Laboratories to explore the energy and mobility impacts of emerging disruptive technologies such as connected and automated vehicles (CAVs), information-based mobility-as-a-service (MaaS) platforms, and advanced powertrain technologies to identify and develop innovative mobility solutions that improve energy productivity, lower costs for families and business, and support the use of secure, domestic energy sources. The EEMS subprogram consists of four primary activities: the SMART (**S**ystems and **M**odeling for **A**ccelerated **R**esearch in **T**ransportation) Mobility National Laboratory Consortium, HPC-enabled data analytics, advanced mobility technology research, and core evaluation and simulation tools. The subprogram's overall goal is to identify pathways and develop innovative technologies and systems that can dramatically improve mobility energy productivity when adopted at scale. The EEMS subprogram is completing the development of a quantitative metric for mobility energy productivity (MEP), which measures the affordability, efficiency, convenience, and economic opportunity derived from the mobility system, which will be used by the program to evaluate success, and by the transportation community to inform planning decisions. The metric will be applicable to both light-duty and heavy-duty vehicles and systems.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0)*. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 3-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
eems007	Mobility Data and Models Informing Smart Cities	Joshua Sperling (NREL)	3-7	3.50	3.75	3.50	N/A	**3.64**
eems009	Modeling and Simulation of Automated Mobility Districts	Venu Garikapati (NREL)	3-9	3.33	3.17	3.33	3.75	**3.30**
eems011	Integrated Mesoscale Urban Systems Modeling with Behavior, Energy, Autonomy, and Mobility (BEAM) to Explore Shared and Automated Vehicles and their Impacts on Energy and Mobility	Zac Needell (LBNL)	3-12	3.17	3.17	3.33	2.75	**3.14**
eems013	ANL Core Tools–Simulation	Aymeric Rousseau (ANL)	3-15	3.00	3.33	3.50	3.17	**3.25**
eems016	Energy-Efficient CAVs	Dominik Karbowski (ANL)	3-18	3.17	3.50	3.00	2.50	**3.23**
eems019	Smart Urban Signal Infrastructure and Control	Hong Wang (ORNL)	3-21	3.25	3.25	3.50	3.00	**3.25**
eems020	Multi-Scenario Assessment of Optimization Opportunities due to Connectivity and Automation	Jackeline Rios-Torres (ORNL)	3-23	3.00	3.17	3.50	3.50	**3.21**
eems023	The Whole Traveler Transportation-Behavior Study	Anna Spurlock (LBNL)	3-26	3.33	3.33	3.67	4.00	**3.46**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
eems027	Multi-Modal Energy Analysis for Freight	Alicia Birky (NREL)	3-29	3.50	3.67	3.67	3.50	**3.60**
eems028	Developing an Eco-Cooperative Automated Control System (Eco-CAC)	Hesham Rakha (Virginia Tech University)	3-32	3.00	3.00	2.83	3.00	**2.98**
eems030	Experimental Evaluation of Eco-Driving Strategies	Wei-Bin Zhang (LBNL)	3-35	2.67	3.00	2.83	2.50	**2.83**
eems031	Traffic Micro-Simulation of Energy Impacts of CAV Concepts at Various Market Penetrations	Hao Liu (LBNL)	3-38	3.25	3.75	3.25	3.25	**3.50**
eems033	Using Passenger Car Cooperative Adaptive Cruise Control (CACC) to Test Operational Energy Consumption at Intersection with Active Traffic Signal Control	Xiao-Yun Lu (LBNL)	3-41	2.83	3.00	2.83	2.50	**2.88**
eems034	Optimization of Intra-City Freight Movement and New Delivery Methods	Amy Moore (ORNL)	3-44	3.33	3.67	3.33	2.83	**3.44**
eems035	Coupling Land-Use Models and Network-Flow Models	Paul Wadell (University of California at Berkeley)	3-47	3.33	3.33	3.33	N/A	**3.33**
eems037	High-Performance Computing (HPC) and Big Data Solutions for Mobility Design and Planning	Jane MacFarlane (LBNL)	3-50	4.00	3.25	3.50	3.25	**3.47**
eems038	Charging and Repositioning Decision Making for Fully Automated Ride-Hailing Fleet	Zonggen Yi (INL)	3-52	3.33	3.67	2.83	3.00	**3.40**
eems039	Charging Infrastructure Design Tradeoffs for a Fleet of Human-Driven and Fully Automated Electric Vehicles in San Francisco	John Smart (INL/LBNL)	3-55	3.75	3.63	3.63	3.67	**3.66**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
eems040	Dynamic Wireless Power Transfer Feasibility	Omer Onar (ORNL)	3-58	3.25	3.00	3.25	3.00	**3.09**
eems041	ANL Core Tools–Hardware	Kevin Stutenberg (ANL)	3-60	3.13	3.50	3.25	3.13	**3.33**
eems044	Quantification of National Energy Impacts of Electrified Shared Mobility with Infrastructure Support	Joann Zhou (ANL)	3-63	3.25	3.00	3.50	3.50	**3.19**
eems045	Focused Validation and Data Collection to SMART Activities	Eric Rask (ANL)	3-65	3.25	3.50	3.25	3.25	**3.38**
eems057	Urban Traveler–Changes and Impacts: Mobility Energy Productivity (MEP) Metric	Venu Garikapati (NREL)	3-67	3.38	3.50	3.38	3.33	**3.43**
eems058	Systems and Modeling for Accelerated Research in Transportation (SMART) Mobility Consortium Tools and Process Development	Aymeric Rousseau (ANL)	3-70	3.75	3.75	3.25	3.50	**3.66**
eems059	Experimental Evaluation of CACC for Passenger Cars	Xiao-Yun Lu (LBNL)	3-72	3.17	2.83	3.50	3.33	**3.06**
eems060	Agent-Based Model and Data Collection for Inter- and Intracity Freight Movement	Monique Stinson (ANL)	3-75	3.50	3.50	3.25	3.25	**3.44**
eems061	Real-Time Data and Simulation for Optimizing Regional Mobility in the United States	Jibonananda Sanyal (ORNL)	3-77	3.00	3.00	3.25	2.75	**3.00**
eems062	Deep-Learning for Connected and Automated Vehicle (CAV) Development	Robert Patton (ORNL)	3-80	3.33	3.33	3.33	3.33	**3.33**
eems063	Ubiquitous Traffic Volume Estimation through Machine-Learning Procedure	Venu Garikapati (NREL)	3-83	3.75	3.50	3.75	3.75	**3.63**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
eems066	Livewire Data Platform–A Solution for Energy Efficient Mobility Systems (EEMS) Data Sharing	Lauren Spath-Luhring (NREL)	3-86	3.38	3.38	3.38	3.00	**3.33**
eems067	Virtual and Physical Proving Ground for Development and Validation of Future Mobility Technologies	Dean Deter (ORNL)	3-91	3.17	3.17	3.50	2.83	**3.17**
eems069	Next-Generation Intelligent Traffic Signal for Multimodal, Shared, and Automated Future	Andrew Powch (Xtelligent)	3-94	3.25	3.25	3.50	3.25	**3.28**
eems072	Charging Infrastructure Needs for Electrification of Freight Delivery Vehicles	Victor Walker (INL)	3-97	3.50	3.38	3.50	3.25	**3.41**
eems074	Smart Cities Topology–Curbs and Parking	Stanley Young (NREL)	3-101	3.00	3.25	3.00	3.50	**3.19**
eems078	Simulation Model Results for Energy and Mobility Impact of Behavioral Scenarios in POLARIS	Joshua Auld (ANL)	3-104	3.25	3.38	3.50	3.00	**3.31**
eems079	Travel-Time Use and Value With Mobility Services	Paul Leiby (ORNL)	3-108	3.50	3.50	3.75	3.50	**3.53**
eems081	Nationwide Energy and Mobility Impacts of CAV Technologies	David Gohlke (ANL)	3-111	3.83	3.67	3.00	N/A	**3.62**
eems082	Validation of Connected and Automated Mobility System Modeling and Simulation	Jeffrey Rupp (American Center for Mobility)	3-114	3.33	3.17	3.83	3.17	**3.29**
eems083	CIRCLES: Congestion Impact Reduction via CAV-in-the-loop Lagrangian Energy Smoothing	Alexandre Bayen (University of California at Berkeley)	3-117	3.50	3.33	3.83	3.00	**3.40**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
eems084	Energy-Efficient Maneuvering of connected and Automated Vehicles (CAVs) with Situational Awareness at Intersections	Sankar Rengarajan (Southwest Research Institute)	3-120	3.25	2.75	3.13	3.25	**2.98**
eems086	Simulation Tool for Energy-Efficient Connected and Automated Vehicle (CAV) Control Development	Dominik Karbowski (ANL)	3-124	3.25	2.50	3.00	3.25	**2.84**
eems087	Computation of Metropolitan-Scale, Quasi-Static Traffic Assignment Models Using High-Performance Computing	Jane MacFarlane (LBNL)	3-126	3.50	3.50	3.50	3.50	**3.50**
eems088	Chicago Transit Authority Transit Network Efficiency and the Changing Mobility Landscape	Joshua Auld (ANL)	3-128	3.17	3.17	2.83	3.17	**3.13**
Overall Average				**3.30**	**3.31**	**3.34**	**3.17**	**3.30**

Presentation Number: eems007
Presentation Title: Mobility Data and Models Informing Smart Cities
Principal Investigator: Joshua Sperling (National Renewable Energy Laboratory)

Presenter

Joshua Sperling, National Renewable Energy Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

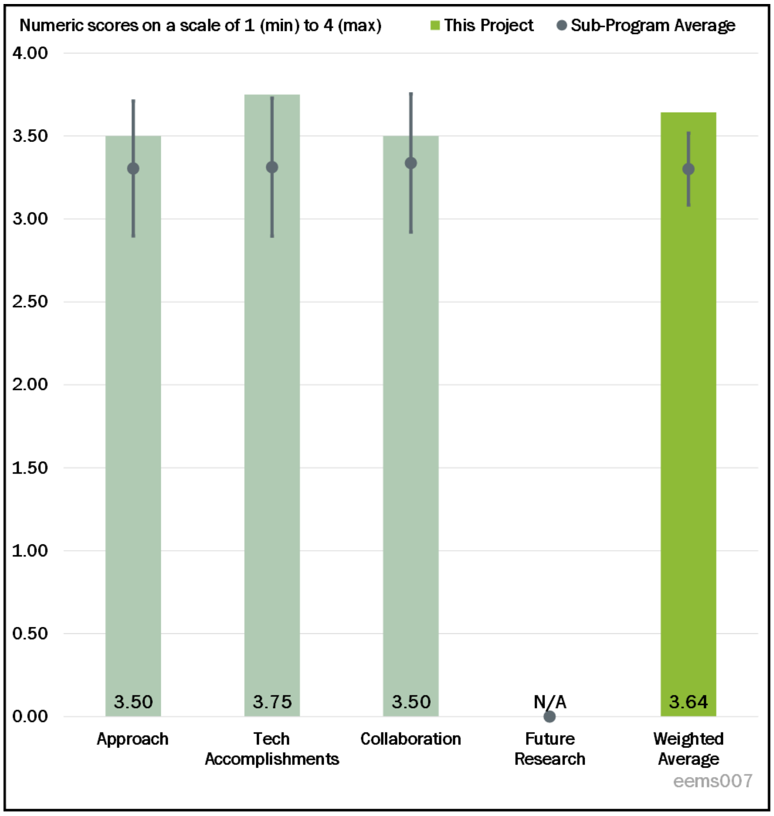

Figure 3-1 - Presentation Number: eems007 Presentation Title: Mobility Data and Models Informing Smart Cities Principal Investigator: Joshua Sperling (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project, which is now mostly complete, has delivered on its goals of analyzing personal travel data in order to conduct quantitative analysis of energy implications in light of emerging mobility options.

Reviewer 2:

The project team focused on readily available data, which makes sense to start, but the team was also cognizant of the need to obtain data to fill gaps. The reviewer was sure it still took effort to obtain the data utilized. The reviewer stated the team also used innovative analysis techniques.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

An impressive publication record was accomplished, including several peer-reviewed journal articles, conference papers, and presentations.

Reviewer 2:

The project team has utilized the data available to expand the understanding of urban mobility related to getting to and from airports (both users and employees), parking, emerging technologies, typology, and more.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration with partners appeared well coordinated and well managed by the Principal Investigator (PI).

Reviewer 2:
A broad team with lots of collaborators contributed.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The project is almost complete.

Reviewer 2:
The project has ended.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer stated energy implications due to emerging personal mobility technologies are one of the important areas in which the Department of Energy (DOE) has interest.

Reviewer 2:
The project provides new insights and data to use for modeling to understand the energy impact of moving people in urban environments.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project seems to have been successfully completed with the allocated resources.

Reviewer 2:
A lot was accomplished, given the resources provided.

Presentation Number: eems009
Presentation Title: Modeling and Simulation of Automated Mobility Districts
Principal Investigator: Venu Garikapati (National Renewable Energy Laboratory)

Presenter

Venu Garikapati, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

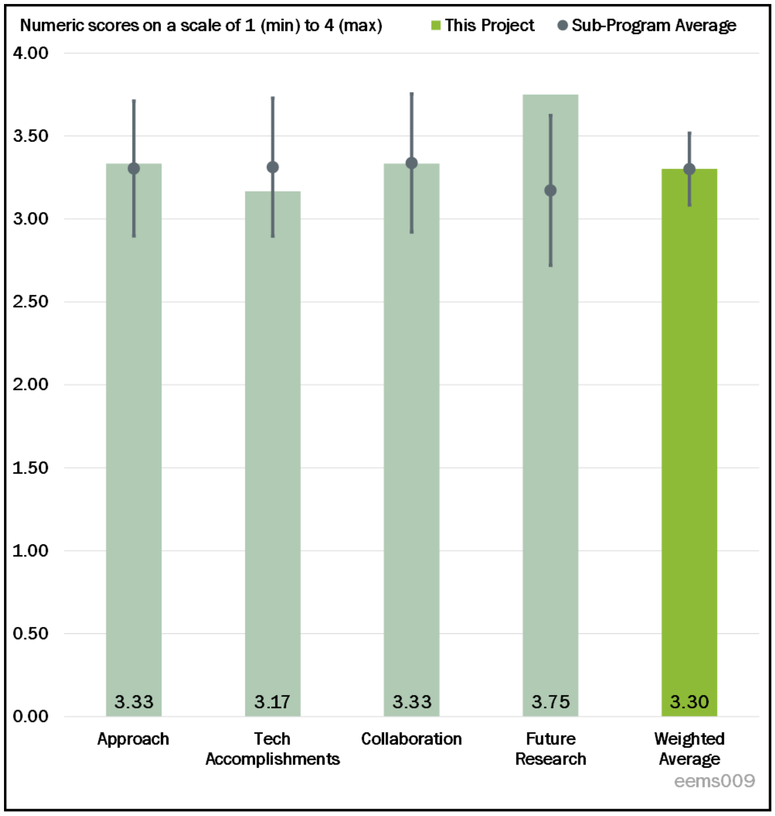

Figure 3-2 - Presentation Number: eems009 Presentation Title: Modeling and Simulation of Automated Mobility Districts Principal Investigator: Venu Garikapati (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed a very good approach to performing the work, which includes building the following models:

- Fleet and Route Optimization Module to determine the optimal configuration (number and capacity) of shuttles and optimal routes to serve a given demand
- Mode-Choice Model to develop a mode-choice model that is responsive to shuttle operations (frequency and capacity) and regional transportation infrastructure
- Automated Mobility District (AMD) Toolkit to exercise in at least one additional deployment location to Greenville, South Carolina, which will help the project team gain insights from early-stage AMD deployments.

Reviewer 2:

This year's project approach built upon previous year's efforts in developing the AMD Toolkit. The Fiscal Year (FY) 2019 approach included determining optimal fleet configurations for meeting specific shuttle demands; developing a mode-choice module for the Toolkit; performing at least one additional case study (beyond Greenville, South Carolina) in an urban location using the Toolkit; and gathering data on early-stage AMD deployments around the country to gain insights.

Reviewer 3:
The objective of developing modeling capabilities that quantify net mobility gains was achieved. Significant effort was placed on coordination with existing mobility districts to obtain data for model development. From the presentation, it appears that the model is based on forcing mode choice (Slide 14) and then quantifying the mobility impacts. This is a bit like calculating the obvious. The reviewer commented that the development tool would be more useful if it predicted the mode choice and then quantified the mobility impact.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
This reviewer noted very detailed work with great results. Technical accomplishments include the following: preliminary AMD simulations using Greenville data; development of an AMD operational configuration optimization module; initiation of mode-choice module development; enhancement of the optimization module; development of a graphical user interface (GUI); implementation of the mode-choice module post-Annual Merit Review (AMR); completed AMD simulations in Austin, with shared and automated vehicles (SAVs) serving as first-mile and last-mile (FMLM) connections to transit; and initiation of the automated shuttle rider survey at the National Renewable Energy Laboratory (NREL).

Reviewer 2:
The researcher indicated that the FY 2019 portion of this 3-year project was completed as of the 2020 AMR. Efforts included enhancing the optimization module by adding a GUI; determining optimal fleet configurations for meeting specific demands; fully incorporating a mode-choice module into the Toolkit; completing case studies for Greenville, South Carolina, and Austin, Texas, using the Toolkit; and reviewing early-stage AMD deployments around the country to gather insights.

Reviewer 3:
The project is complete and met its objective of quantifying impacts.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team had very good collaborations between academia, National Laboratories, and city governments, which are not always easy.

Reviewer 2:
The collaboration with Greenville and Austin is impressive and provides great support to the DOE objective of identifying levers that improve energy productivity by utilizing real-world data and interfacing with those operating mobility systems.

Reviewer 3:
The researcher presented on good collaborative efforts with various universities, a municipal government, and a nonprofit organization. The researcher also stated collaborative efforts with other National Laboratories but did not offer details on these efforts as related to this year's project efforts.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer reported that proposed future research includes incorporating additional mobility-on-demand (MOD) modes, such as shared bikes, electric scooters (e-scooters), and SAVs for FMLM connections; integrating the Toolkit into a regional travel-demand model, such as Austin's regional travel model in the

context of FMLM simulations; and focusing on FMLM simulations, including enhancing operational logic with features like dynamic ridesharing and deadhead minimization, in addition to rising demand levels and system size.

Reviewer 2:
Although this 3-year project has been completed, the researcher suggested future work involving incorporation of MOD modes into the Toolkit; full integration of the Toolkit with regional travel-demand models for greater utility; and using FMLM connections in the simulations. It is also recommended that the researcher continues collecting information through data and surveys (including the NREL survey) for further input to, and validation of, the Toolkit.

Reviewer 3:
Not applicable was indicated by this reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project supports the overall DOE objectives by quantifying the net mobility gains and energy impacts of automated, connected, electric, and/or shared (ACES) vehicles deployed in dense urban districts.

Reviewer 2:
The project-developed methodology will provide a basic quantification of AMD energy impacts. While great uncertainties and estimations exist in the quantification, it is a good first step and is commensurate in detail with the volume of real-world data available for validation.

Reviewer 3:
The project is relevant for DOE's program as it addresses the need for modeling and simulation tools for assessing advanced mobility technologies in various urban and suburban settings. The project's focus on AMDs allows for later application of its results to broader and more complex regional environments.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed sufficient resources for this project; however, these studies should continue to help build AMDs.

Reviewer 2:
The project team fulfilled objectives on schedule, indicating resources were sufficient.

Reviewer 3:
At about $250,000 per fiscal year, the researcher has made significant progress on a comprehensive work plan, including FY 2019. The researcher intimated that additional funding for more in-depth data collection that supports and validates the AMD toolkit would be useful.

Presentation Number: eems011
Presentation Title: Integrated Mesoscale Urban Systems Modeling with Behavior, Energy, Autonomy, and Mobility (BEAM) to Explore Shared and Automated Vehicles and their Impacts on Energy and Mobility
Principal Investigator: Zac Needell (Lawrence Berkeley National Laboratory)

Presenter

Zach Needell, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 33% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

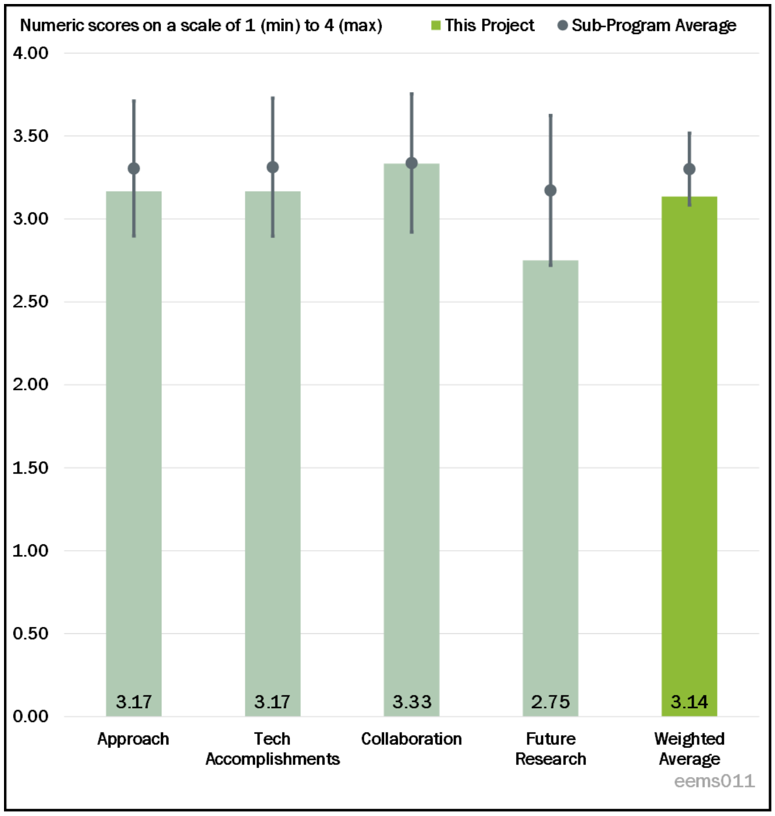

Figure 3-3 - Presentation Number: eems011 Presentation Title: Integrated Mesoscale Urban Systems Modeling with Behavior, Energy, Autonomy, and Mobility (BEAM) to Explore Shared and Automated Vehicles and their Impacts on Energy and Mobility Principal

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The overall approach was excellent. The reviewer's only concern is that the project involves the fairly complicated integration of multiple models in a way that may not always yield expected results.

Reviewer 2:

The modeling could benefit from greater sensitivity analyses and real-world validation, as previous reviewers have noted, particularly in light of recent events. Ridership patterns, transit use, parking, and vehicle miles may be permanently changed. Further, characterization of other emerging factors should also be considered, such as teleworking, electronic commerce (e-commerce), and micro-mobility.

Reviewer 3:

The workflow seems comprehensive, but judging from the analytical results, the project's contribution to the understanding of system impacts of major mobility trends, as stated in the barriers section on Slide 2, remains to be realized. For example, the results only show impacts from light-duty (LD) vehicles, even though one would imagine that micro-transit is a viable option where medium-duty (MD) vehicles are utilized. It was not clear to the reviewer whether this is due to the lack of modeling capabilities or simply a choice of what to show in the results. In any case, focusing solely on LD passenger movement only paints a fraction of the whole picture.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The technical accomplishments and progress were excellent. In at least one aspect, they would have been improved by documenting and highlighting the assumptions behind transportation network company (TNC) deadheading and its effect on congestion throughout the results and whether the deadheading was an input or an output of the model. An increasing body of literature is finding that TNC effects on congestion, even with shared mobility, may be a net negative due to the deadheading effects on congestion.

Reviewer 2:
The analysis has made significant progress in creating an integrated model of highly complex systems. As a policy tool, however, it may be limited by the availability of data for validation, particularly on emerging and disruptive trends as they relate to various urban transportation systems, so that longer range scenarios can be analyzed for applying policy tools.

Reviewer 3:
The reviewer would have liked to see more insights resulting from a project this size. Judging from the presentation, the results are mostly on ride sharing and automation. The chart on Slide 19 indicates that the impacts of these trends are not much over the base scenario. It is also not clear whether improvements in mobility energy productivity (MEP) are statistically significant or practically meaningful.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This project involved many high-impact and relevant collaborators at all levels and with geographic diversity. Therefore, the reviewer rated this element as outstanding.

Reviewer 2:
The collaboration is very (northern) California-centric, which is not typical in many respects to other urban areas.

Reviewer 3:
Slide 22 indicates that there is collaboration on charging behavior and infrastructure, but the results did not show anything related to electrification or charging. The extent of collaboration that took place was unclear to this reviewer.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer indicated that there is always more a researcher can propose, and the project suggestions were useful to review. Perhaps the project could have benefited from an increased focus on real-world impacts, use, and implementation rather than a focus on modeling.

Reviewer 2:
The project has ended. While the future research stated on Slide 25 makes intuitive sense, it is difficult to judge whether or not it is technically achievable without seeing a detailed work plan.

Reviewer 3:
This reviewer reported that the project ended.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project supports DOE's current objectives.

Reviewer 2:
Creating an agent-based transportation model is certainly within DOE objectives. The only concern would be any overlap or duplicative efforts with similar projects.

Reviewer 3:
The project supports DOE objectives in that it shows the impact of sharing and automation on mobility and energy. The question is, now that this project has shown that there is not much impact, should DOE keep pursuing further analyses or the implementation of such technologies?

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources seem sufficient for the work produced.

Reviewer 2:
The resources and funding are appropriate for the development of the analysis tool.

Reviewer 3:
The reviewer would have expected more scenarios analyzed, given the size of the project.

Presentation Number: eems013
Presentation Title: ANL Core Tools—Simulation
Principal Investigator: Aymeric Rousseau (Argonne National Laboratory)

Presenter

Aymeric Rousseau, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

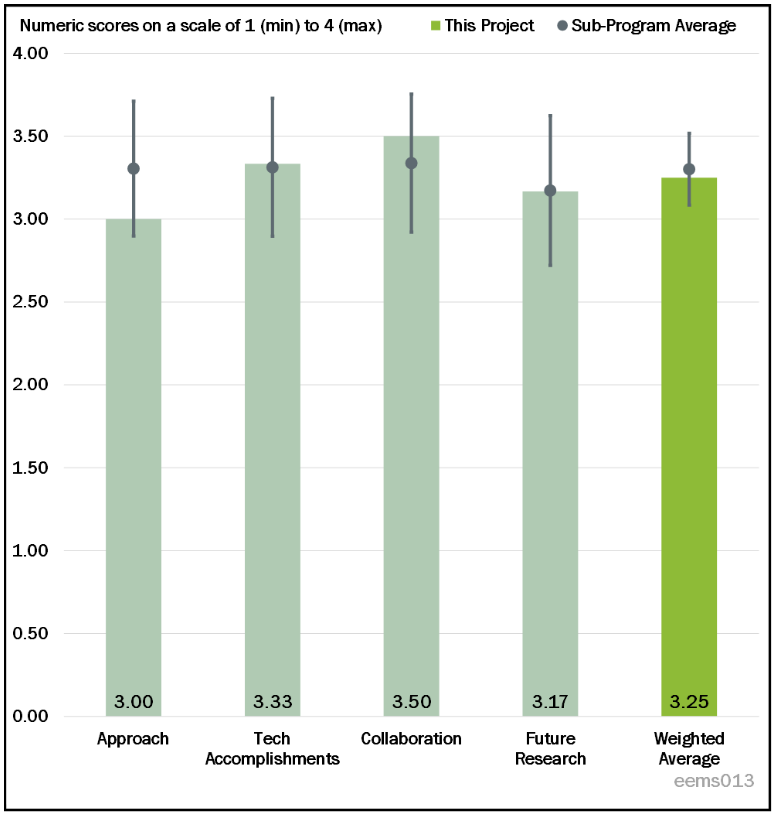

Figure 3-4 - Presentation Number: eems013 Presentation Title: ANL Core Tools—Simulation Principal Investigator: Aymeric Rousseau (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The tools being developed are appropriate for vehicle and mobility system modeling. The automation techniques and user aids (workflows) are enablers for efficiently completing large studies.

Reviewer 2:
The tools updated as part of this project are part of an integrated Advanced Model Based Engineering Resource (AMBER) environment, which has an Autonomie focus, and allows for a new generation of workflow management.

Reviewer 3:
The list of barriers and challenges speaks to the fundamental problem of precision and depth the project team wants to go. There is a lot of feedback between the different models and modules. The project team has a grand vision, but each handoff embeds uncertainty in compounding and escalating levels. Until these fundamental issues are clearly addressed and pass extensive validation and review, it is hard to see how advancing depth of the research will add additional, useful output to inform decision making.

Using the phase “fairly good representation of real world cycles” creates a concern. Are the representations useful or not? Do they provide sufficient representation or not? The team needs to be clear on what the threshold or target is and if the work is meeting it. Vague words like “fairly” suggest work may have fallen short.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Improved user interfaces, enabling millions of simulation runs via AMBER, and reusing vehicle models with changes are all important accomplishments. Heavy-duty (HD) electrification was an appropriate use case evaluation selection.

Reviewer 2:
Progress has been very good in meeting the project milestones for creating and improving the AMBER tool ecosystem functionality. It is slightly unclear which technical accomplishments were completed during the review period.

Reviewer 3:
The ability to reuse part of a vehicle to create a new one is notable. Although there is clear value in what was accomplished, the reviewer questioned the reported times. According to the reviewer, 5 seconds seems unreasonably fast, as it can take more than that just to interact with the GUI. A more complete explanation with more, real examples and context will help the reviewer in evaluating the extent of this accomplishment.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The partners listed represent a broad spectrum of the user audience for the tool suite. The data needed to validate tool results are generally available.

Reviewer 2:
The project has a substantial and diverse set of collaborators that appear to have been engaged and contributed. The reviewer thought more explicit illustration of the coordination and contributions between and from the partners will help. In some ways, the number adds substantial complexity and requires very careful management.

Reviewer 3:
The project team has good collaboration with numerous Systems and Modeling for Accelerated Research in Transportation (SMART) Consortium partners for input updates, outputs to inform Energy Efficient Mobility Systems (EEMS) research, and evaluation of Vehicle Technologies Office (VTO) program benefits. The reviewer indicated it was nice to see leveraging of U.S. Driving Research and Innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE) and the 21st Century Truck Partnership (21CTP) for updated information. The reviewer suggested the team consider inputs from California deployment projects like California Air Resources Board's (CARB) Zero and Near-Zero Emissions Freight Facilities (ZANZEFF) Class 8 to validate modeling results for HD electrification.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
There is a good plan in place for tool improvements and distribution of models.

Reviewer 2:
The project team proposed relevant future research, including AMBER refinement, benefits evaluation of different use-cases, and license-free, compiled tunable model availability.

Reviewer 3:
The project team should list the priority of the proposed future work. MD and HD vehicle incorporation may be more important than adding more complexity to the model.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project develops foundational tools used in many VTO studies and analyses.

Reviewer 2:
Autonomie's use by a range of DOE projects, industry, and other end-users speaks to its utility in addressing fundamental research and design questions.

Reviewer 3:
This work is directly relevant in many different aspects, including evaluating program benefits; using as a tool for enabling EEMS research; quantifying the effects of changes in vehicle components and vehicle types across different applications; and conducting large-scale simulations to measure fuel economy and petroleum use impacts.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Funding appears adequate, and the project appears to be on schedule.

Reviewer 2:
The reviewer stated $3.75 million over 3 years seems appropriate based on the importance and high use of these tools.

Reviewer 3:
The reviewer indicated sufficient resources because additional budget is not needed. However, there is a lack of clarity on how the specific budget is allocated; so, it may be excessive.

Presentation Number: eems016
Presentation Title: Energy-Efficient CAVs
Principal Investigator: Dominik Karbowski (Argonne National Laboratory)

Presenter

Dominik Karbowski, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

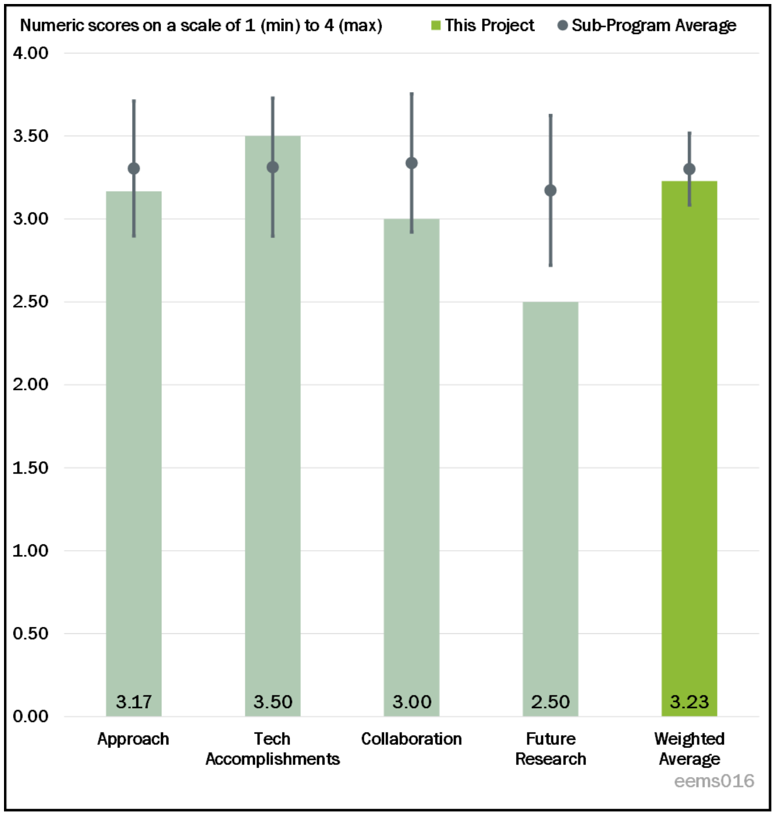

Figure 3-5 - Presentation Number: eems016 Presentation Title: Energy-Efficient CAVs Principal Investigator: Dominik Karbowski (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The subproblems studied in this project are highly relevant to the barriers being addressed for improved connected and autonomous vehicle (CAV) energy efficiency. One caveat is that propagating this work to industry is not explicitly addressed. Because there are no CAVs of this kind studied in the wild, some work could be done to make the implementations adoptable (software toolkits and proposed vehicle interface standards).

Reviewer 2:

Plans and milestones for evaluating energy use and associated validation were generally outlined in the presentation. The research also incorporated a range of scenarios (e.g., Slide 12). Regarding barriers and other challenges, the project team did recognize that the sample is not designed to be statistically representative of the U.S. “driving mix” (urban versus rural, highway versus arterial, etc.).

Reviewer 3:

According to the reviewer, major items noted in the prior review remain. Specifically, the controlled and stylized model did not, and still does not, have a clear path forward to address the major limiting factors for usefulness. Traffic is not considered, overall system efficiency cannot be measured, and true optimality is hard to achieve. Lack of time consideration as a motivator for current driving patterns also makes it hard to relate to improved performance in a real application.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Results and technical accomplishments show high value of the technology and set a suitable carrot for further investigation by industry. Progress appeared excellent to the reviewer.

Reviewer 2:
The project ended in September of 2019 and is 100% complete. The milestones for 2019 Quarter (Q) 3 and Q4 were specifically discussed and are marked as “complete” on Slide 6.

Reviewer 3:
The work progressed and met the requirements. In that regard, the work overcame barriers. It is still difficult to translate these technical accomplishments into fully implementable and actionable outputs for the design of systems. The benefit is primarily still limited to computer simulation and may be difficult to extend to the real world with future work.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team made good use of existing data sets via external partners and the simulation tools developed at Argonne National Laboratory (ANL).

Reviewer 2:
Collaborations with external partners outside of the research group are limited and did not indicate close coordination beyond some data-sharing with Lawrence Berkley National Laboratory (LBNL) and Lawrence Livermore National Laboratory (LLNL).

Reviewer 3:
The presentation generally notes that work was done as part of a partnership between ANL (lead) and both LLNL and LBNL (data testing). Relative to other presentations, the reviewer indicated that there were fewer details outlining the specifics regarding coordination between the groups.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The next steps are logical. A gap exists in some sort of standards development since vehicle connectivity is an important part of the work.

Reviewer 2:
The project has ended. However, the presentation does note areas for potential future research such as increased real-world demonstration and validation.

Reviewer 3:
The proposed future work lacks clarity in the description to adequately evaluate. The addition of traffic considerations is important, but what the project team wants to do and how the team wants to do this are not clear. This extends to the other future work proposals, of which all lack decision points. The project has ended, and future work relates to proposed additional funding requests.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project demonstrates the possibilities of future technologies in CAVs that can have an impact on vehicle and transportation system energy consumption reduction, which is a key DOE VTO mission.

Reviewer 2:
This project aims to explore the energy impacts of CAV technology and eco-driving. The project supports DOE's goal of promoting efficient use of energy resources and supporting a more economically competitive, environmentally responsible, secure, and resilient U.S. energy infrastructure.

Reviewer 3:
The reviewer believed the work met the DOE objectives as stated but asserted that the objectives are not well articulated in the presentation. In theory, the work can be implemented in the real world, but it is not clear that it should be or will translate into comparable performance. So, by the letter, yes, the work met the objective.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project is on schedule and resources appear to be adequate for the tasks envisioned.

Reviewer 2:
This project has ended. It appeared that the funding was sufficient to conduct the planned work.

Reviewer 3:
Project funding seems generally sufficient. While additional funding could help support further validation and improved implementation, the project seems to have been able to complete milestones with the budgeted resources.

Presentation Number: eems019
Presentation Title: Smart Urban Signal Infrastructure and Control
Principal Investigator: Hong Wang (Oak Ridge National Laboratory)

Presenter

Hong Wang, Oak Ridge National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

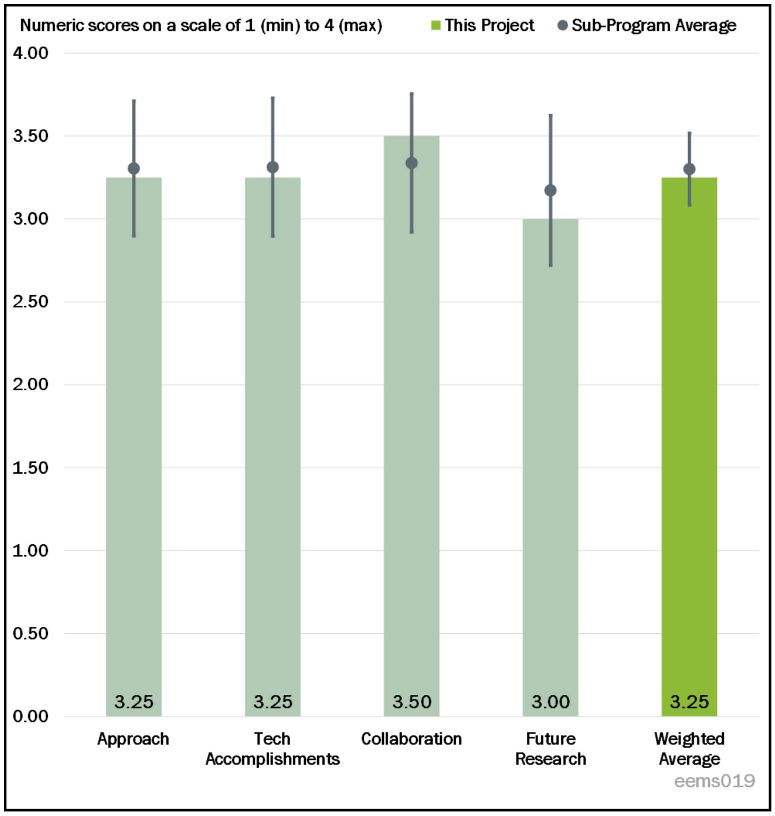

Figure 3-6 - Presentation Number: eems019 Presentation Title: Smart Urban Signal Infrastructure and Control Principal Investigator: Hong Wang (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach seems very good and is fairly straightforward, as this is purely a traffic simulation-based study. Three different traffic-control algorithms are being assessed for performance in reducing vehicle delays in a traffic network based in Bellevue, Washington.

Reviewer 2:

The proposed multi-input and multi-output (MIMO) control problem formulation is interesting. The case study of networked signals so far is still over simplified. A more realistic setting would be desired where heuristic methods may be needed to balance the optimality and real-time performance.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The technical accomplishments appear to be good. Three different traffic-signal control methods were tested on a simulation network of Bellevue, Washington, and the results of these control algorithms are presented. The results are focused on the total traffic delay of all vehicles on the network. It is unclear if estimates of fuel and energy savings will also be calculated and presented, but these were not presented in the poster. It would also be good if there were some measure provided for traffic progression. Since the control algorithms are using an intersection-centric control optimization approach, it would be good to understand if there were any “green progressions” or “green waves” that emerged from the intersection-centric optimization.

Reviewer 2:
The technical accomplishment and progress are reasonable. The reviewer would have expected a more efficient algorithm for realistic scenarios.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
According to the poster, the collaboration among the project team is good and the effort is well coordinated.

Reviewer 2:
Collaboration appears to be very good. However, there are only two entities involved in this study: Oak Ridge National Laboratory (ORNL) and NREL.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
There is very limited information in the poster about future research, but there is a mention of exploring dynamic and stochastic control methods and integrating adaptive routing. There is no mention of studying the energy impacts in the results, so it is unclear if all of the results will remain only in terms of traffic delay.

Reviewer 2:
The future direction mentioned by the PI is generally effective, but a more detailed explanation and/or plan would be desired to gauge this criterion.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Networked traffic-signal control is very important and effective for improving system-wide energy efficiency in transportation. From the reviewer’s point of view, the combination of signal control and vehicle control is expected to bring significant benefits to the entire system.

Reviewer 2:
Yes, this project is relevant in that it is developing new traffic-control algorithms that have the potential to reduce traffic delays at intersections in an urban road grid network.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The experience and resources of the PI and project team should be sufficient to achieve the stated milestone in a timely fashion.

Reviewer 2:
The reviewer could only assume that resources are sufficient because there was no funding information available in the poster.

Presentation Number: eems020
Presentation Title: Multi-Scenario Assessment of Optimization Opportunities due to Connectivity and Automation
Principal Investigator: Jackeline Rios-Torres (Oak Ridge National Laboratory)

Presenter

Jackeline Rios-Torres, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

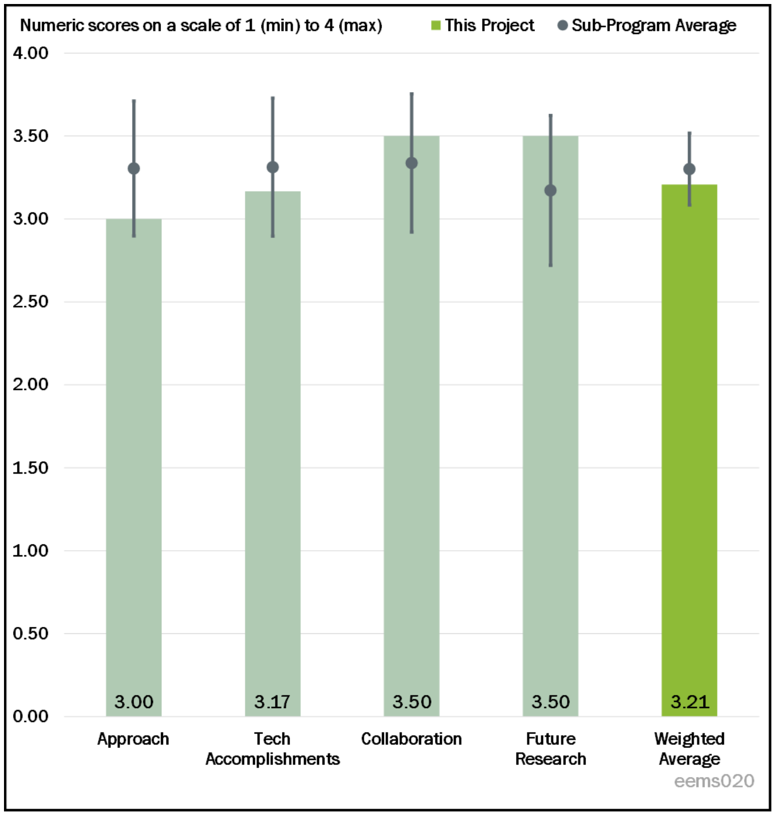

Figure 3-7 - Presentation Number: eems020 Presentation Title: Multi-Scenario Assessment of Optimization Opportunities due to Connectivity and Automation Principal Investigator: Jackeline Rios-Torres (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project's goal was to explore optimization opportunities to increase energy efficiency in full and partial CAV market penetration under diverse scenarios. A simulation-based assessment, optimization opportunities, and fuel, emissions, energy, and safety implications were the outcome of a literature review, target scenario definitions, and optimal coordination frameworks.

Reviewer 2:

Overall, the approach was good but somewhat narrow in its use of a single-driver model (which is quite inaccurate and likely to heavily influence the energy results) and focus on on-ramps. Both were acknowledged as opportunities for improvement.

Reviewer 3:

The reviewer's primary concerns with the approach were mainly with the calibration and validation of both the autonomous vehicle (AV) and the human driver, car-following, and lane-changing models.

The project team mentioned that the built-in AV driving logics (cautious, all-knowing, etc.) were used. However, did the team validate the AV driving behavior? Based on other research, the reviewer was uncomfortable with the way that the VISSIM driving logics were derived. The reviewer explained that VISSIM models AV driving behavior using the Wiedemann model (which was originally derived using theory on human drivers' perception of objects and reaction to stimuli). Albeit the models are calibrated to AV driving behavior by reducing driving behavior variance (on the relative speed-relative spacing plane) to emulate that the AVs are perfectly following the vehicle in front of them. However, the Wiedemann model was derived based on human behavior, and the reviewer was not convinced that using AV driving data to calibrate the model guarantees that it will properly emulate AV driving behavior. Although interested in hearing about third parties that have validated the driving logics, the reviewer has yet to see this in the literature. Most researchers using the VISSIM platform are continuing to emulate customized AV driving behavior using DriverModel.dll for this reason. The reviewer asked why the ANL vehicle models were not implemented using the VISSIM COM interface to improve the AV modeling behavior conducted as part of the project team's analysis.

Moreover, given that mixed traffic analyses were part of the primary technical outcomes of this project, the reviewer was concerned about how rigorously the human driving behavior component was calibrated. Many traffic-flow modelers are vocal about the need to collect data about human driving behavior in the presence of an AV. It will be important for performance forecasts to understand how human drivers change behavior in the presence of an AV. However, the project team mentioned that loop detector data were used to calibrate the human driving behavior (Wiedemann) model, which is not likely to capture these behavioral discrepancies. Additionally, there is a growing body of literature that highlights that traffic-flow simulators—VISSIM and Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks (AIMSUN)—may produce realistic traffic-flow behaviors while significantly distorting vehicle trajectories (which are required as inputs to safety and emissions models). One of the ways to overcome this is by using vehicle trajectory data, not loop detector data, to calibrate and validate the car-following and lane-changing models.

To have confidence in the team's technical accomplishments (i.e., simulated scenarios in Ann Arbor and Interstate-75 (I-75) in Tennessee), it is important that the team is using well calibrated and validated car-following and lane-changing models in the micro-simulation models, because these model outputs are used as emissions model inputs. However, for the reasons listed previously, the reviewer had concerns about the quality and rigor of the team's calibration of both the AV and human-driver behavior portion of the model.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The project was completed on time; thus, technical progress was rated as excellent. The reviewer would have liked to see the performance indicators used to measure project success, but this information was not given in the slides.

Reviewer 2:

A comprehensive emissions and efficiency analysis of several scenarios (single merge and corridor) has shown that merging coordination has the potential for significant emissions and fuel consumption reductions (3%-30%).

Reviewer 3:

Technical accomplishments and progress were good. It seems like some opportunities for running more scenarios and/or expanding the model capability may have been missed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Overall, the collaboration was excellent, including the collaboration for calibrating some scenarios to a portion of I-75 in Tennessee. Collaboration could have been improved if more federal partners had been enlisted (e.g., the Federal Highway Administration [FHWA], National Highway Traffic Safety Administration [NHTSA]), or perhaps some automobile original equipment manufacturers (OEM)s for some reality checks on CAV technology capabilities.

Reviewer 2:
The reviewer reported collaboration among the five DOE SMART Mobility Consortium National Laboratories as well as with the University of Delaware and the University of Tennessee.

Reviewer 3:
Although it was hard for this reviewer to assess project collaboration when only one member of the team is presenting, the project was completed on time. Thus, it seems to be safe to assume that the collaboration worked well on this team.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future research largely captured many of the shortcomings of the current research, which was excellent.

Reviewer 2:
The project has ended, although several relevant aspects for future research were mentioned.

Reviewer 3:
This reviewer stated that the project has ended.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project's overall intention of modeling energy use within CAVs is clearly aligned with DOE objectives.

Reviewer 2:
As the introduction of CAVs primarily deals with safety, this project investigated the energy and emissions impacts of partial to full penetration of CAV scenarios.

Reviewer 3:
Yes, the project contributes to overall DOE objectives. Having the ability to test multiple scenarios to evaluate energy impacts is important, and this project contributes to that area. This reviewer highlighted the following: Goal 1—Tools, Techniques, and Capabilities to Understand and Improve MEP; and Goal 3—Insight Sharing, Stakeholder Coordination, and Collaboration on Local and Regional Transportation Systems.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked that $1 million in funding for a 3-year project involving multi-partner collaboration seems appropriate for the outlined scope of work.

Reviewer 2:
The resources were not vast, and some of the results indicated modest. However, it is not clear if more funding would have necessarily resulted in enough of a deeper dive, producing useful and meaningful results (i.e., maybe resources would have, or maybe they would not have).

Reviewer 3:
The project has ended, but the budget seems higher than what would be expected for the project accomplishments.

Presentation Number: eems023
Presentation Title: The Whole Traveler Transportation-Behavior Study
Principal Investigator: Anna Spurlock (Lawrence Berkeley National Laboratory)

Presenter

Anna Spurlock, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 33% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

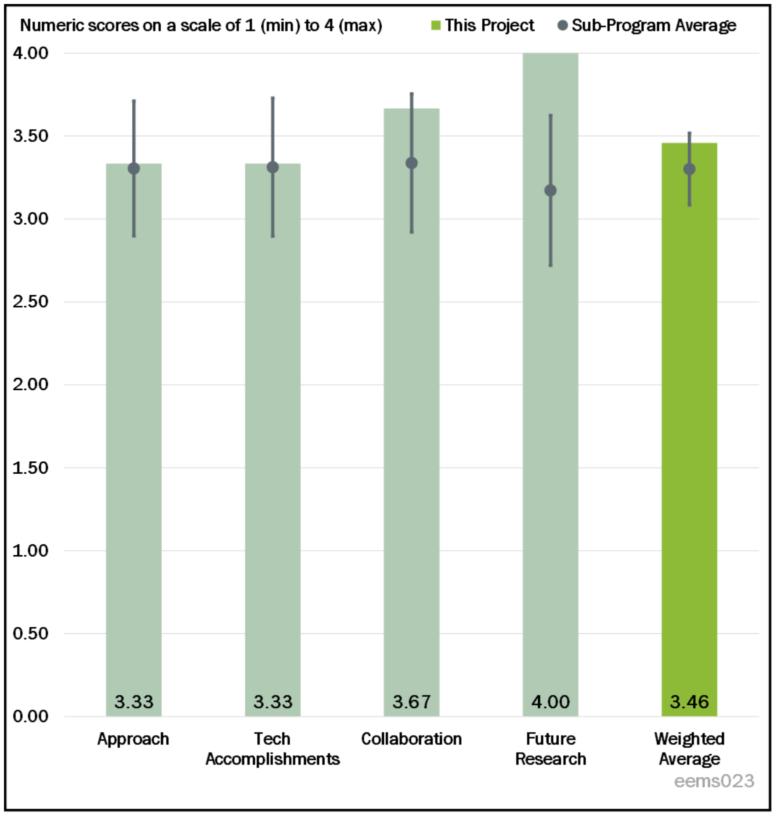

Figure 3-8 - Presentation Number: eems023 Presentation Title: The Whole Traveler Transportation-Behavior Study Principal Investigator: Anna Spurlock (Lawrence Berkeley National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach was well thought out by designing a traveler household survey supported by global positioning system (GPS) trip data collection and innovative analytics to extract the findings of travel choice patterns, preferences, and decision-making processes with the advent of new mobility technologies' multiple time scales. New mobility technologies considered in the study included electric vehicles (EVs), ride sharing, CAVs, ride-hailing and shared mobility, and e-commerce.

Reviewer 2:

The project is well designed and has addressed the barriers. Innovative and broad approaches and topics were explored. If the WholeTraveler data were more representative across the whole socioeconomic spectrum, then this project would be rated as outstanding.

Reviewer 3:

The project has multiple interesting threads and research questions, and it addresses important behavioral questions. However, it was hard for the reviewer to get an overall picture of the project design.

The barrier cited is uncertainty regarding energy impact of new mobility technologies due to a lack of understanding of traveler behavior. While the project has identified interesting relationships between life course and travel behavior and vehicle choice, this year's work does not seem designed to deliver insights on new mobility adoption.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The GPS location dataset was a big part of this year's effort and making it available to the public should be useful. However, it does not seem that the project itself was able to make use of the data before it ended.

Overall, the project has substantial technical accomplishments leading to numerous papers and presentations. It is also noteworthy that the Phase 1 data have been shared with researchers from six laboratories and academia, and that both Phase 1 and Phase 2 data will be made available on the Livewire Platform.

Reviewer 2:
The project has resulted in a depth of new knowledge with very interesting and broad topics being explored and analyzed in the whole transportation system. This reviewer emphasized that GPS data cleaning is always more complicated than it seems. Having the cleaned (and anonymized) data available to all is very valuable on its own.

Reviewer 3:
The survey data provided insights and resources to improve accuracy and flexibility of transportation system simulation models and reduce uncertainty associated with behavioral and human factors in the transportation-as-a-system modeling and scenario analysis. Anonymized versions of the survey data (including GPS trips) will be available to DOE National Laboratories and external researchers via the DOE Livewire Platform. Gender gaps in vehicle ownerships and spatial mobility when entering parenthood have been identified and studied.

It is unfortunate that the GPS data collected on traveler trips were unavailable until toward the end of the project, and therefore were not available for detailed analysis. Also, while previously acknowledged, a go/no-go decision to collect information in another geographic setting perhaps limited the broader applicability of this data set to other regions with different characteristics.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There was significant collaboration among three National Laboratories, four universities, and a survey subcontractor. The project was effectively managed to deliver the listed accomplishments.

Reviewer 2:
There is a large project team, and the presenter noted that members "have coordinated in an integrated way." The publications include a large number of authors.

Reviewer 3:
According to the reviewer, collaboration across the team was necessary with such an ambitious, broad, and detailed undertaking.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The project ended in June of 2020. There are three projects proposed for SMART Mobility 2.0 that build off of work done in this project.

Reviewer 2:
The project has ended, although future research is proposed for SMART Mobility 2.0.

Reviewer 3:
The project has ended, but the project team has also proposed future research. The proposed Mobility and Technology Insight Validation Evidence (MOTIVE) work builds from lessons learned from the current project. Including underrepresented groups and a broad geographic area are a plus. Similarly, focusing on key data gaps needed for modeling is also important. The proposed workflow for SMART Mobility 2.0 would also contribute to improving future modeling.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Yes, this project conducted early-stage research enabling an understanding of the individual behavioral and economic drivers of, and barriers to, increased MEP for emerging transportation technologies and services. This contributes to EEMS research, whose goal is to achieve an affordable, efficient, safe, and accessible transportation future in which mobility is decoupled from energy consumption.

Reviewer 2:
This data collection and analysis directly contribute to a better understanding of transportation choices across a broad spectrum of topics—emerging technologies, EVs, gender, life cycle, etc.

Reviewer 3:
To date, the results seem somewhat disconnected from saving energy, though eventually better understanding behavioral issues will be important to support the deployment of new mobility options.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This project was a significant effort in the EEMS research area as it spanned 3.5 years and was funded with $3.2 million. It also included significant partner collaboration with other laboratories and universities, which is commensurate with the level of funding.

Reviewer 2:
The project was ambitious, but the team was able to accomplish so much with the resources given.

Reviewer 3:
Given the recurring concern that the survey respondents were not a representative sample, it seems possible that additional funding would have been helpful to achieve the stated milestones.

Presentation Number: eems027
Presentation Title: Multi-Modal Energy Analysis for Freight
Principal Investigator: Alicia Birky (National Renewable Energy Laboratory)

Presenter

Alicia Birky, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

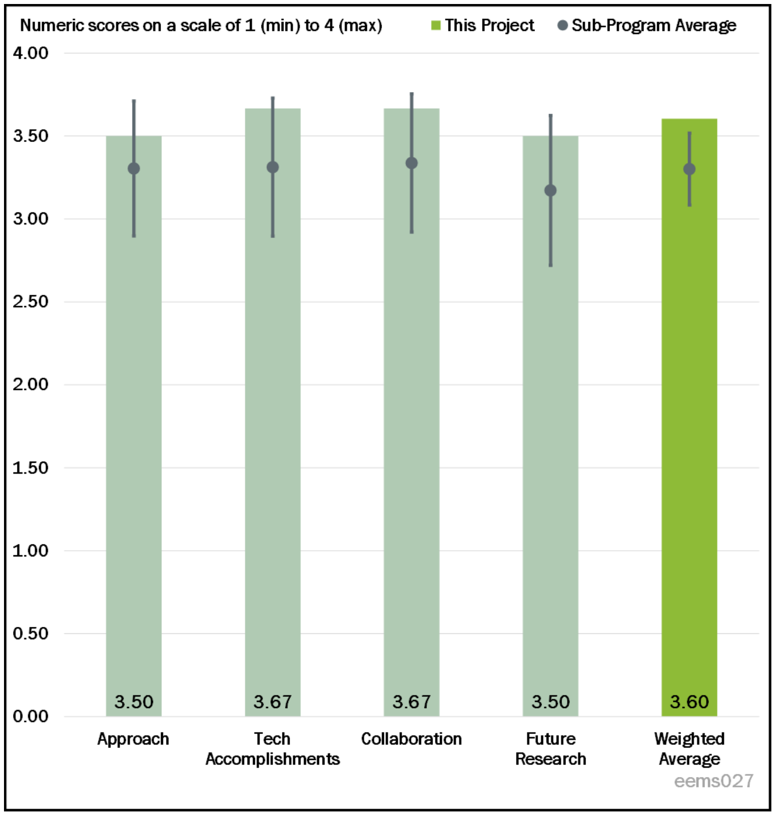

Figure 3-9 - Presentation Number: eems027 Presentation Title: Multi-Modal Energy Analysis for Freight Principal Investigator: Alicia Birky (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project team has a very good approach by maintaining consistency across other freight modeling and analysis efforts within the SMART Consortium, including the Freight Analysis Framework (FAF) zoning structure and methodologies. The team also applied the national truck flow model to refine estimates of a national potential for energy reduction from truck platooning and developed multi-modal, intercity, freight-energy models to allow analysis of Chicago's regional and national impact of emerging technologies.

Reviewer 2:

For an initial project in this area, the approach was sound. This short project now offers a good structure for future efforts.

Reviewer 3:

The project comes up with what in theory seems like an effective way to determine the energy-savings opportunities from the application of emerging technologies on intercity freight, given the complex network of freight movement. Additionally, creating the freight mobility energy productivity (F-MEP) will translate the results of the study into an easily understandable measure for relevant stakeholders.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project provided a flexible framework that can be applied at various geographic scales and decomposed by commodity or mode. Input was easily obtained from existing data or freight models to compare scenario outcomes. Technical accomplishments reported by this reviewer include the following: development of a national truck flow model; assignments to local and highway links supporting workflow modeling and informing platooning analysis; truck proximity for platoon formation and capacity impacts; proven savings of 9.5% across the platoonable highway segments; and savings depend on vehicle type, platoon size, inter-truck gap, and road type.

Reviewer 2:
The project appears to be on track, and all key technical analyses have been completed. Comments from previous years appear to have been incorporated into model updates.

Reviewer 3:
Although a number of solid technical accomplishments were observed, the reviewer commented that the project team seemed somewhat unstructured—a lot of good work that did not seem to connect enough. Again, this is an example of an initial, short, project in freight analysis, which is very important. The reviewer believed project two will accomplish a great deal.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team and collaboration among the team—NREL, ANL, the University of Illinois at Chicago, INRIX, the U.S. Department of Transportation (DOT), the U.S. Census Bureau,, the U.S. Bureau of Labor Statistics, the American Trucking Associations, the American Transportation Research Institute, and the Surface Transportation Board—was very strong.

Reviewer 2:
The project team sufficiently used expertise at other laboratories for this effort. The reviewer expected more collaboration as these efforts become more tactical in nature. Collaborations with companies, and maybe even nonprofit non-governmental organizations (NGOs), will be very helpful.

Reviewer 3:
Partners represent a good variety of interested stakeholders and research organizations. The work seems to have been split up into equal chunks for each provider.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Future research ideas are practical and good. Prior to and during future work, the reviewer suggested engaging key government agencies, NGOs, and even private companies on which areas of research in this area will be most helpful.

Reviewer 2:
Yes, proposed research for future analysis grows on research already done and strives to refine modeling while answering any outstanding questions.

Reviewer 3:
This reviewer reported the following future research:

- Expand and refine truck movement/platooning model to analyze the energy impact of other connectivity and automation technologies.
- Validate network assignment and improvement of temporal distributions using INRIX data analysis.
- Integrate with multi-modal intercity freight energy (MMIFE) models to evaluate feedbacks.
- Develop plausible inputs for MMIFE scenarios with academic and industry partners.
- Refine parameterization.
- Extrapolate trucking collaborative logistics—cost impacts, load factors, empty movements.
- Refine intercity F-MEP.
- Engage academic, industry, and planners for stakeholder feedback or integration with multi-modal energy models to refine F-MEP as a tool for scenario evaluation.
- Work with industry and university partners to improve freight data and methodologies to reduce uncertainty.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project supports DOE objectives by qualifying the intercity freight-energy reduction opportunity space to define the regional and national energy impacts of SMART Mobility freight transportation technology and inform public and private sector decision makers.

Reviewer 2:
The reviewer stated that EEMS is a really important area for goods movement energy reductions.

Reviewer 3:
Part of EEMS's purview is to attempt to understand how passenger and freight mobility is changing, given the rise of emerging technology options and new information and communications technology. This project fits well into that space and makes a distinct attempt to assign energy reduction impacts to those applications, which will be useful to cities and states striving to create sustainable transportation systems.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project had sufficient resources and should continue this important work.

Reviewer 2:
Project resources seemed sufficient to the reviewer.

Reviewer 3:
The project appears to be well funded, which is appropriate given the scope of the analysis.

Presentation Number: eems028
Presentation Title: Developing an Eco-Cooperative Automated Control System (Eco-CAC)
Principal Investigator: Hesham Rakha (Virginia Tech University)

Presenter

Hesham Rakha, Virginia Tech University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

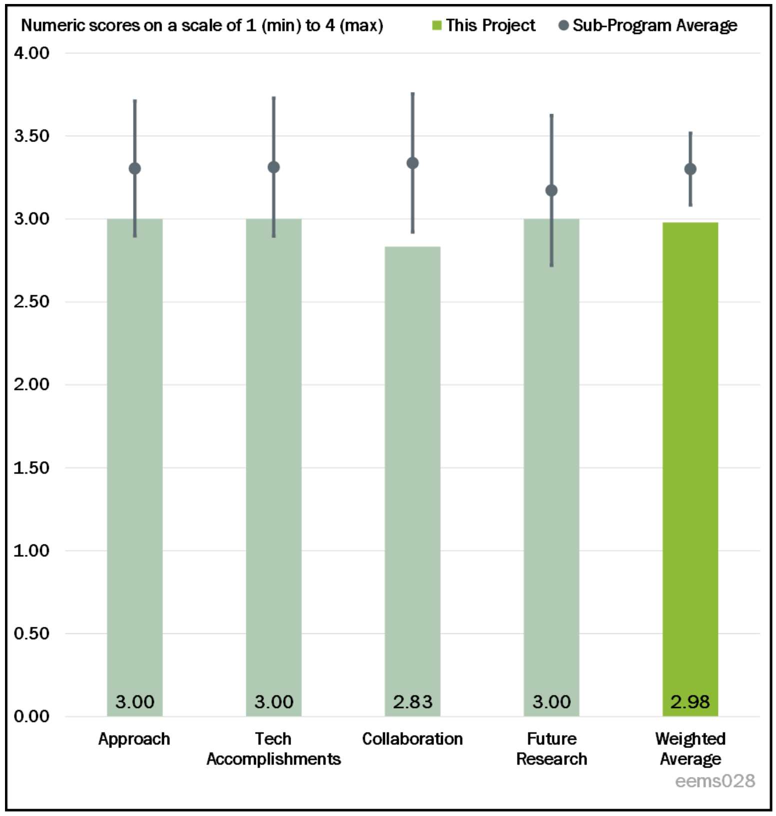

Figure 3-10 - Presentation Number: eems028 Presentation Title: Developing an Eco-Cooperative Automated Control System (Eco-CAC) Principal Investigator: Hesham Rakha (Virginia Tech University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer stated the project team took a relevant approach to performing the work.

Reviewer 2:
The design of the work seems sound, and the focus on accounting for different powertrain types is useful. Work thus far has assumed 100% CAVs; it is not clear that scenarios of partial CAV penetration will be included, but that would be very useful.

Reviewer 3:
Overall, the project approach made sense to the reviewer. One issue that is not very clear is how well the INTEGRATION tool can simulate the microscopic-level behavior (vehicle dynamics) of the real-world vehicle. It is always reported that large-scale simulation calibration at the microscopic level (for energy estimation purposes) is very challenging. Also, the computational time to include multi-level optimization is another concern.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The original date of completion is listed as June 30, 2020, but the percentage of work that has been done is about 75% (maybe due to the breakout of COVID-19). According to the PI’s presentation, a no-cost extension

(NCE) has been approved, which should address some concerns of the reviewers on the technical accomplishment and progress. It is very good to see the publication record from this project.

Reviewer 2:
Some project findings were highlighted, but the reviewer was not sure about the ability to compare them with those of other researchers.

Reviewer 3:
Milestone completion dates are not consistent with an end date of June 2020, but researchers have requested a no-cost extension. It does not appear that the project team has yet finished integrating multiple CAV applications, which is the first goal listed.

One finding was that, with an increasing percentage of EVs, the optimal speed of platooned vehicles declines to an unacceptably low level (38 kilometers per hour at 45% EVs). The presenter noted that a multi-objective function, including energy and time, would be required to achieve a more reasonable outcome. The reviewer said that range should be considered as an objective as well. Also, a conclusion that platooning light-duty vehicles (LDVs) is not useful as EVs become widespread would be helpful information.

Differences in percentage reduction of greenhouse gas (GHG) and fuel use on Slide 9 were not adequately explained.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer indicated that collaboration and coordination across the project team was only vaguely described.

Reviewer 2:
No partners are funded by DOE, but collaboration with others (e.g., OEMs, state DOTs) will help ensure relevance of the work in the real world.

Reviewer 3:
In this presentation, the PI highlighted more of the algorithm development and simulation work. The reviewer stated that it would be better to see more involvement from the industrial partners—Toyota and Ford—besides the provision of test vehicles.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer reported that the project is ending this year.

Reviewer 2:
Proposed future research is limited to completion of ongoing work.

Reviewer 3:
Some unaddressed technical barriers identified by the reviewer include the application of actuated or adaptive signal control; and consideration of lateral control to potentially improve the efficiency and energy consumption of eco-vehicle(s) as well as the entire traffic flow.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The primary objective of the project is to reduce vehicle energy use by using vehicle control strategies and CAV applications. The subject eco-cooperated automated control (eco-CAC) system is projected to achieve 20% energy savings, which is a large improvement. Hence, this supports the overall DOE objectives.

Reviewer 2:
The work is going in the right direction, but the reviewer was not sure how findings could be applied more broadly.

Reviewer 3:
This project should support the overall DOE objective. Based on the reviewer's knowledge, the DOE Advanced Research Projects Agency-Energy (ARPA-E) NEXT-Generation Energy Technologies for Connected and Automated On-Road Vehicles (NEXTCAR) Program has sponsored a few teams performing work similar to what is shown here. It would be interesting to compare all of these results.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer thought the project resources should be sufficient, and that the delayed project delivery date was possibly due to the COVID-19 breakout.

Reviewer 2:
The project is behind relative to initial milestone dates, but there is no indication of insufficient funding.

Reviewer 3:
This reviewer reported that the project is ending.

Presentation Number: eems030 Presentation Title: Experimental Evaluation of Eco-Driving Strategies Principal Investigator: Wei Zhang-Bin (Lawrence Berkeley National Laboratory)

Presenter

Wei-Bin Zhang, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

67% of reviewers indicated that the project was relevant to current DOE objectives, 33% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

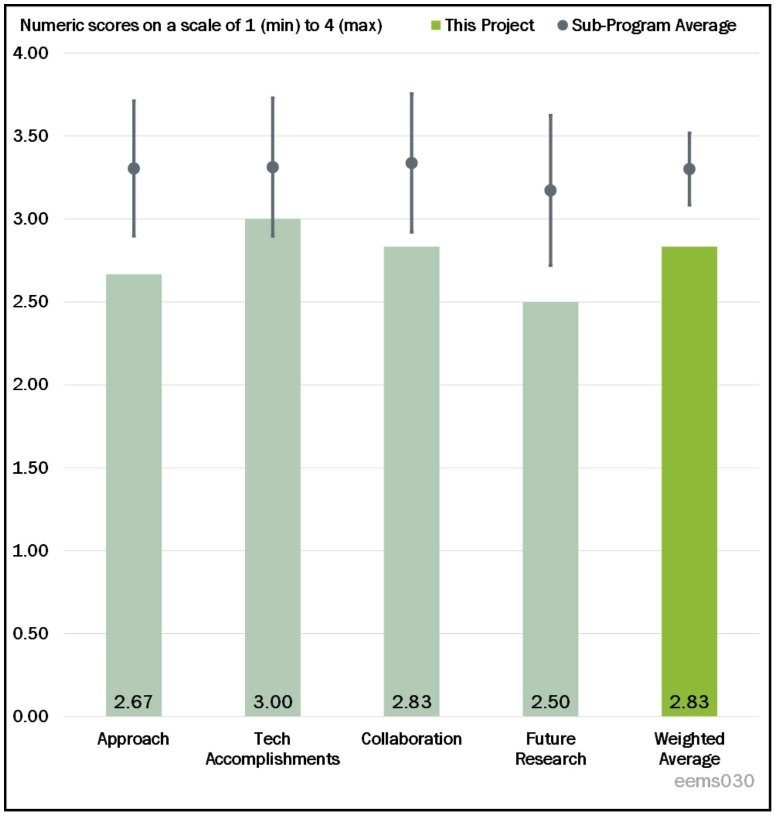

Figure 3-11 - Presentation Number: eems030 Presentation Title: Experimental Evaluation of Eco-Driving Strategies Principal Investigator: Wei Zhang-Bin (Lawrence Berkeley National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project identified potential opportunities for eco-driving strategies and quantified the energy benefits and environmental impacts. Real-world data were collected for arterial corridors and local intersections to support the analyses of unproductive energy consumption.

Reviewer 2:

The reviewer described a fairly known approach.

Reviewer 3:

After careful consideration and review, the reviewer concluded that the project approach has some fundamental flaws and limitations. After the presentation and discussion, it remains unclear how this can really extrapolate real-world motivations—fuel saved versus time, induced congestion, etc. This is difficult to reconcile with the stated objective of real-world application and realistically answering how much eco-driving can save.

A fundamental question on how much of the gains were from a change in method was unanswered and does not give confidence in utility of the results.

The work focuses on potential savings of individual vehicles but does not consider systemic effects, including loss of potential efficiency in other vehicles due to changes in velocity; cars that cross intersections before the light changes; and other congestion-related effects that are tradeoffs.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The accomplishments and progress are technically sound.

Reviewer 2:
The project team collected 2 days of vehicle trajectory level traffic data at 14 intersections in the San Francisco Bay area. Field evaluation of eco-approach and departure (EAD) was conducted using five experimental vehicles at the testing corridor in San Jose. Extensive traffic analyses were conducted for one signalized intersection and one unsignalized intersection. Moderate fuel savings of 10%-20% per event were realized, but fuel savings at a trip level are less than 1% on average. Therefore, the fuel-savings benefit of EAD at the intersection level is insignificant.

Reviewer 3:
The study failed to extract truly unproductive (avoidable via eco-driving) fuel consumption, from fuel consumption due to safety regulations and performance tradeoffs. The project team acknowledged that much of what is considered fuel waste is not an eco-driving issue. Because the data used are very specific and not generalizable, it is difficult to extract value.

The data and output were too limited to provide meaningful evidence against the relevant desired outcomes. The results cannot inform realistic energy savings from eco-driving; at best, results can provide an upper bound. The field experiments were too limited in scope to be extensible to almost all real-world conditions.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration with San Jose State University and data sharing with DOE's SMART Mobility Consortium were reported by this reviewer.

Reviewer 2:
The reviewer noted that not much collaboration across the project team was highlighted.

Reviewer 3:
Collaborations across the project team were adequate, but did not really add critical skills or input.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The project has ended. Future collaborations between LBNL, Texas A&M University, and ANL were suggested to develop national-level data needed to support the analysis of wasted and unproductive fuel consumption. Additional field-data collection and analyses were suggested that seem appropriate.

Reviewer 2:
This reviewer reported that the project ended.

Reviewer 3:
Although the concept outlined by the project team has merit, the narrative lacks any information on how future work will be conducted; address barriers and challenges to completing; and enumerate decision points to track value and progress.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer stated that an understanding of unproductive fuel consumption at a regional and national level is necessary to understand how technologies and measures could be implemented to reduce vehicular fuel consumption.

Reviewer 2:
The reviewer saw this as an average project.

Reviewer 3:
The reviewer was unclear as to what objective the project supports and is less sure that the results and output support general objectives of informing overall energy savings at the national level.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
At $460,000 of funding over 2 years, this was a relatively small project that showed that EAD at the intersection level would not yield significant fuel savings. However, the project team also showed the importance of understanding where unproductive fuel use occurs.

Reviewer 2:
Resources are sufficient to support the full-time staff (or equivalent) working on this project, and the amount of staff should be sufficient to execute the work.

Reviewer 3:
This reviewer commented that the project ended.

Presentation Number: eems031
Presentation Title: Traffic Micro-Simulation of Energy Impacts of CAV Concepts at Various Market Penetrations
Principal Investigator: Hao Liu (Lawrence Berkeley National Laboratory)

Presenter

Hao Liu, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

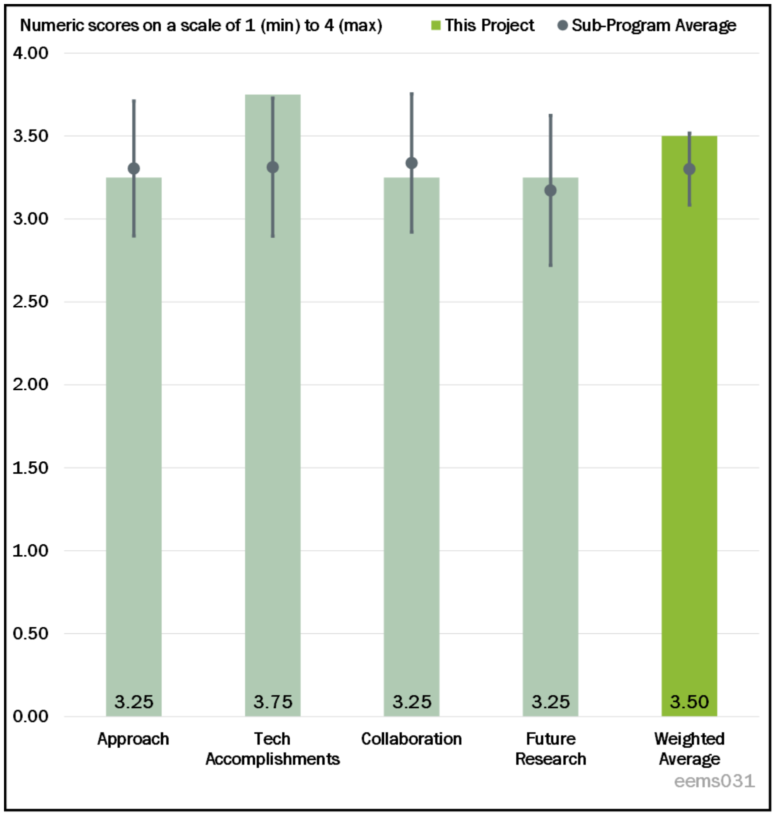

Figure 3-12 - Presentation Number: eems031 Presentation Title: Traffic Micro-Simulation of Energy Impacts of CAV Concepts at Various Market Penetrations Principal Investigator: Hao Liu (Lawrence Berkeley National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project is focused on intersection control (new signal control algorithms and centralized vehicle trajectory control) and active traffic management (ATM) strategies for improving freeway traffic flow. A special emphasis is placed on addressing the uncertainty of system performance under partial CAV penetration scenarios. As real-world field testing of the impact of CAVs on energy savings is highly expensive, this project takes an early modeling approach to identify possible opportunities and associated benefits for intersections and on the freeway under various CAV penetration scenarios. It has developed an operational-level micro-simulation model in Aimsun.

The approach incorporates two principal elements. First, it includes development of a cooperative signaling algorithm, both with and without trajectory planning. This includes identifying the optimal signal-phase sequence, signal timing, and number of stages, as well as incorporating trajectory planning. This approach utilizes a simple algorithm relying on prediction of two vehicle states: passing without slowing down and passing after joining the queue. The second element—modeling freeway mobility and energy performance—looks at two cases. This includes an isolated freeway merge bottleneck (incorporating ramp metering [RM]) and a real-world freeway corridor (California State Route 99) scenarios under various ATM strategies. ATM strategies include local responsive ramp metering (LRRM), coordinated ramp metering (CRM), and variable speed advisory (VSA). In short, the freeway modeling looks at three ways to improve flow at ramp bottlenecks, including local, whole corridor, and regulating the speed of freeway sections upstream.

The Motor Vehicle Emission Simulator (MOVES) model is used to estimate vehicle energy consumption. Overall, the approach seems reasonable and well designed.

Reviewer 2:
The interaction between vehicles and roadway infrastructure to optimize traffic flow is a key enabler to make CAVs effective. The exploration of practical, implementable approaches is very welcome.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
A good synopsis is provided of the technical barriers, including the rapid evolution of vehicle technologies and services enabled by connectivity and automation and determining the value and productivity derived from new mobility technologies. In general, the project is responsive to these technical barriers.

A new signal control optimization algorithm, V2, has been demonstrated through simulation to save energy (up to 30%-40%) in saturated conditions. This is achieved via fewer decelerations and vehicles in queue that can pass through intersections without waiting for multiple cycles. The results diminish at higher cooperative adaptive cruise control (CACC) vehicle market penetrations. It was also found that the benefit of including trajectory planning is small.

For the performance of freeways at isolated bottlenecks, it was found that the use of LRRM eliminates capacity drop and improves traffic mobility and performance. For a freeway corridor, LRRM improves performance in mobility and fuel consumption. CRM and VSA both achieved improvements of more than 20% in mobility, fuel consumption, and emissions.

In short, the modeling results indicate the potential of the new control algorithms and ATM strategies to improve the overall performance at both the local intersection level and on the freeway at ramp bottlenecks. Specifically, the results show average energy efficiency improvements of 1%-30%, especially in saturated conditions with CACC market penetrations of 15%-30%.

The project has demonstrated a solid list of modeling results with some promising mobility and energy performance benefits. The project is now successfully complete and has achieved all of the milestones.

Reviewer 2:
Significant progress has been made in proving the outlined concepts. In addition, how to implement the accomplishments has been addressed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The partners are closely aligned in terms of tools and data sharing.

Reviewer 2:
Overall, for an early modeling activity, project collaboration and coordination are good. Collaboration with ANL is mentioned about better understanding and potentially using Autonomie to better quantify the vehicle-side response and benefits of the proposed traffic-control algorithms. The extent of collaboration with ORNL is less clear, though.

The PI did mention that outputs of this study are used by EEMS075—General Microsimulation to Meso-Simulation Workflow—but some additional detail regarding this would have been useful to the reviewer.

This project fits well into the EEMS end-to-end modeling workflow at the microscopic traffic-flow level.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The next steps are logical and build on current project progress.

Reviewer 2:
As presented, it appears that many of the remaining challenges and barriers surround the need for greater accuracy and resolution of models, whether estimating vehicle travel distances, human driver behavior, or vehicle acceleration and deceleration. Also, there is a need to better understand queue length to enable better signal control and trajectory planning. In short, the project proposes further examination and refinement of algorithms and fidelity of modeling results. Subsequently, the project should expand efforts to arterial corridors.

There are a number of reasonable proposals for future work, but the project is still strictly an upfront, theoretical modeling activity. As technology quickly progresses and implementation becomes more and more of a reality, questions arise with regard to this project moving forward. Where do proposed future efforts converge? How would the project team prioritize the proposed future activities, especially if only limited funding could be provided? Also, has any research been done to determine if the proposed signaling algorithms and freeway strategies are compatible with existing signaling infrastructure? Has any initial outreach/coordination been done to reach Metropolitan Planning Organizations (MPOs) and/or commercial signaling companies (e.g., Econolite) to discuss compatibility and commercialization realities regarding implementing new signaling technologies? If follow-on efforts are in the works for this project, it may be beneficial to expand communication and coordination with these entities upfront to better understand real-world constraints and adjust future modeling strategies and approaches accordingly to enable compatibility and future technology transfer.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Traffic congestion is a significant barrier to transportation energy consumption. The project results show the benefits of coordinated control of on road vehicle movement.

Reviewer 2:
The project is relevant as it strives to identify methodologies to maximize mobility and vehicle energy efficiency at intersections via new CAV communication capabilities. It also is looking to develop ATM strategies for improved freeway mobility and energy performance. Successful development and implementation of either of these elements would improve overall vehicle-system mobility, energy efficiency, and emissions.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources provided for this task were essentially appropriate and have allowed for timely, on-schedule completion of project milestones and deliverables.

Reviewer 2:
The project appears to be adequately funded.

Presentation Number: eems033 Presentation Title: Using Passenger Car Cooperative Adaptive Cruise Control (CACC) to Test Operational Energy Consumption at Intersection with Active Traffic Signal Control Principal Investigator: Xiao Lu-Yun (Lawrence Berkeley National Laboratory)

Presenter

Xiao-Yun Lu, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 33% of reviewers indicated that the resources were sufficient, 67% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

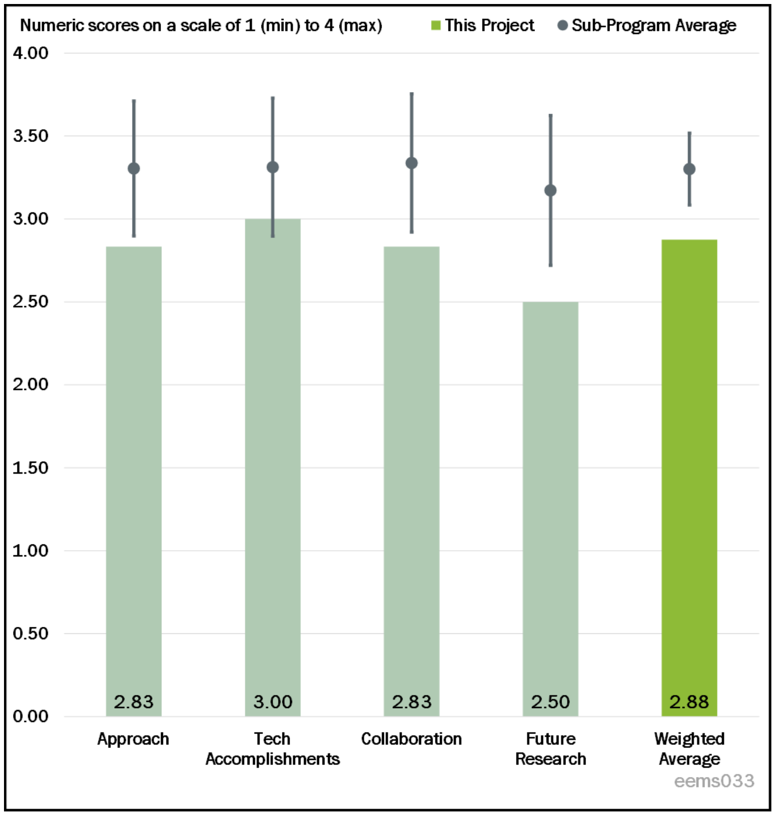

Figure 3-13 - Presentation Number: eems033 Presentation Title: Using Passenger Car Cooperative Adaptive Cruise Control (CACC) to Test Operational Energy Consumption at Intersection with Active Traffic Signal Control Principal Investigator: Xiao Lu-Yun

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The presentation was good and was presented in an easily digestible form.

Reviewer 2:

The reviewer noted that the switch from trucks to cars is significant for the project scope. These vehicles operate completely differently and by different operators. The project will have little to no value in the trucking industry for these reasons.

Reviewer 3:

The reviewer had trouble understanding the full approach and the problem being solved. The change from HD trucks to cars should have been more fully discussed to better understand how this impacted the project goals. The reviewer offered kudos for making the adjustment, but since the project will be completed in the next few months, it would have been good for the team to finalize the approach and suggest next steps for future research more directly.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project team adopted new algorithms developed under CAV Task 1.2, which were different from what had been developed and simulated under this project in FY 2019. Good simulation data were collected.

Reviewer 2:
The project seems to capture the necessary background.

Reviewer 3:
Data were presented that supported the completed testing and various real tests supported by simulation. However, key findings are not well understood. What did this work tell us? What should be done next? These were too unclear for this reviewer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Good work was done among participating team members and on redirection of the truck versus car plan. The reviewer stated this was well done. The reviewer is supportive of more industry involvement, even if serving as an advisor on these projects.

Reviewer 2:
Some project collaborations were highlighted.

Reviewer 3:
Project delays have caused Volvo not to respond to low-speed issues. The reviewer thought there should have been more OEM support for the project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The project team should use these data to support a project with several truck OEMs.

Reviewer 2:
The proposed future research is well stated, but the reviewer thought that it should be tied to a few overarching project objectives. It seems this work is making good contributions, but the end result is unclear. Because a potential follow-on effort is being decided, answering this question is important.

Reviewer 3:
The reviewer commented that the project is ending soon.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is relevant.

Reviewer 2:
The project is tackling relevant issues.

Reviewer 3:
The project supports the overall DOE objectives, but it does not offer much more value than the studies that are already complete.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project team needs more truck OEMs and industry input from trucking companies.

Reviewer 2:
There are multiple remaining challenges (listed on Slide 18) and little time and budget left.

Reviewer 3:
This reviewer reported that the project is ending soon.

Presentation Number: eems034
Presentation Title: Optimization of Intra-City Freight Movement and New Delivery Methods
Principal Investigator: Amy Moore (Oak Ridge National Laboratory)

Presenter

Amy Moore, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 33% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

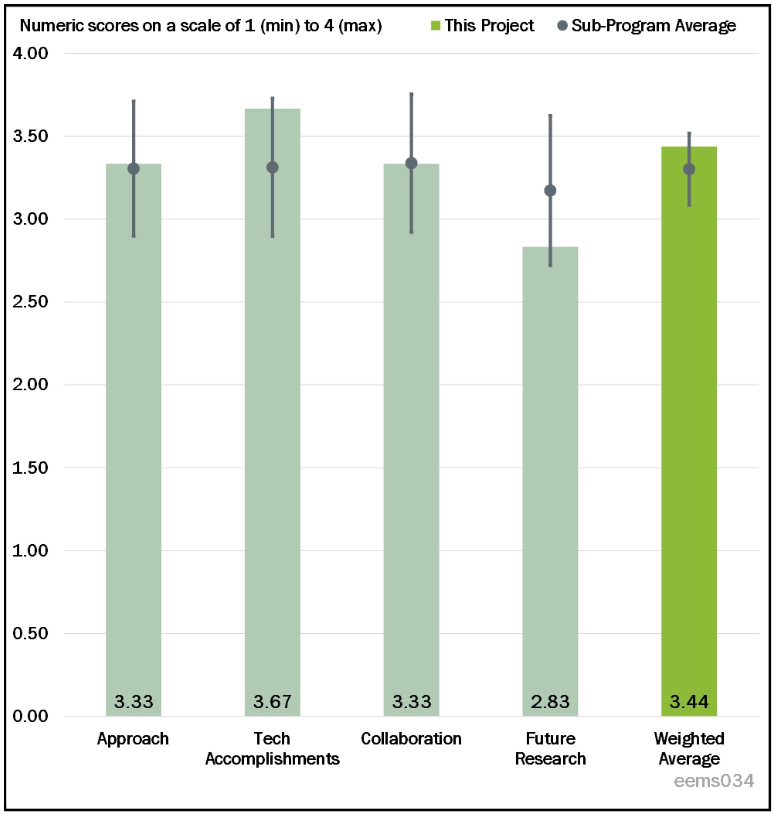

Figure 3-14 - Presentation Number: eems034 Presentation Title: Optimization of Intra-City Freight Movement and New Delivery Methods Principal Investigator: Amy Moore (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project looked at many options and groups of options concerning energy use of packages in e-commerce. Over the course of a few years, some have been added and others have been changed. This project kept up with these challenges well.

Reviewer 2:

The reviewer observed an excellent, long-term project approach that successively built upon each previous year's accomplishments. This year's research had a nice blend of emerging technology testing and delivery scenario development and modeling. The team made great use of United Parcel Service (UPS) delivery data for providing real-world input to the modeling effort.

Reviewer 3:

The reviewer believed the project team did an excellent job presenting the possibilities, with a few exceptions. The reviewer would have given the team an outstanding mark had it taken into account the differences in gas, diesel, electric, and propane as the fuels to compare because they are real-world fuels used in the transportation sector. The team could have also taken lockers into consideration, in addition to other carriers that come into the same neighborhood, street, or house several times a day, increasing emissions and traffic.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
This year's research provided valuable insights into new freight delivery methods, both individually and in combination relative to an established urban baseline. The research provided a greater understanding of drone delivery capabilities and energy use in the context of urban delivery and supported the expansion of Planning and Operations Language for Agent-based Integrated Simulation (POLARIS) for assessing freight delivery impacts. Based on the presentation, it appears significant progress was made in FY 2019 in completing the remaining milestones, as well as presenting project results in a number of relevant forums in FY 2020.

Reviewer 2:
Based on the report, the reviewer believed that the project team adequately covered the goals it set out to cover. The team even saw a little into the future with drone deployments, but also realized drones currently are not a very efficient delivery method other than for short distances with a light payload.

Reviewer 3:
The presentation showed the energy use of various scenarios well and tried to keep the conditions the same to enable comparisons, which is really hard (e.g., when a consumer uses a car for the final move of packages home and combines this with other trips). The reviewer commented that this could have been even better, but care was taken by the researchers. The reviewer also thought drone efforts were a little too much. It seems as if this project spent too many resources on testing drones.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Considering the team was spread out, the reviewer thought that assigning the different groups to a specific part of the project was a good use of time and resources.

Reviewer 2:
The reviewer observed very nice collaboration among multiple research, industry, and government organizations. Team members brought specific and relevant expertise to the project. There was great collaboration for meeting this year's project objectives among ORNL and other National Laboratories. The reviewer highlighted INL (freight modeling and drone testing); NREL (delivery mode energy use); LBNL (e-commerce and consumer data); and ANL (POLARIS model). The project team also made good use of relevant data sources, such as UPS, Federal Express (FedEx), and the City of Chicago government.

Reviewer 3:
The reviewer tended to believe that many VTO projects should have more industry collaboration. How about conducting surveys, or other information-gathering using partners? The reviewer thought that some organizations may actually be willing to do this at no cost. Not picking on the project too much on this, it is a good example of how desired information on benefits or consequences of one scenario versus another could be gathered through surveys or interviews.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The presenter indicated that the proposed future work would involve additional collaboration with ANL to further expand POLARIS's freight modeling capabilities for evaluation of e-commerce and its effects on urban transportation. The presenter also hinted at expanded drone testing, which is assumed to be conducted by INL. Both of these elements would extend the valuable research platform of this project as related to freight delivery

methods and energy impacts. The presenter also alluded to extending a similar research approach to other cities (Atlanta, Knoxville, Chattanooga, Austin, Detroit) in addressing last year's research comments. This multi-metropolitan research could also be an important element of future research in terms of evaluating similar freight delivery methods in different urban settings. Further, it is assumed that the researchers will address some of the data challenges identified as part of any future research plans.

Reviewer 2:
The reviewer did not know if there is much left in dissecting drone use or the effect that e-commerce has on freight mobility. During this pandemic, it is pretty clear that people are restricting outside movement and more things are being ordered for home delivery. Also, unless drone legislation or drone size changes, there will not be much to discuss in that arena.

Reviewer 3:
The reviewer was not sure additional drone testing is needed and asked if future research could better compare alternatives on other benefits and consequences. The reviewer thought that this is needed more than more work specifically on the energy use.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The research is very relevant to DOE's programs, given the need for understanding the energy impacts of increasing congestion and vehicle populations, growth in e-commerce, and emerging freight movement technologies in urban environments. The results provide a valuable research platform for evaluating additional freight delivery scenarios and technologies under a variety of metropolitan conditions.

Reviewer 2:
Vehicle technology will play a huge role in emissions, and because freight is a major contributor, the reviewer thought it is important to make it a major part of the conversation.

Reviewer 3:

With some reservations, fuel use is a smaller part of some of the issues with e-commerce, but the reviewer thought that VTO has a responsibility to help understand them.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The funding level appears to be sufficient for the efforts prescribed and multiple organizations involved.

Reviewer 2:
The reviewer did not know if it is possible, but suggested that there needs to be more data collection from other organizations, not just UPS. FedEx and Amazon may show different trends if they are added to the mix.

Reviewer 3:
Project resources are okay.

Presentation Number: eems035
Presentation Title: Coupling Land-Use Models and Network-Flow Models
Principal Investigator: Paul Wadell (University of California at Berkeley)

Presenter

University of California at Berkeley

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 33% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

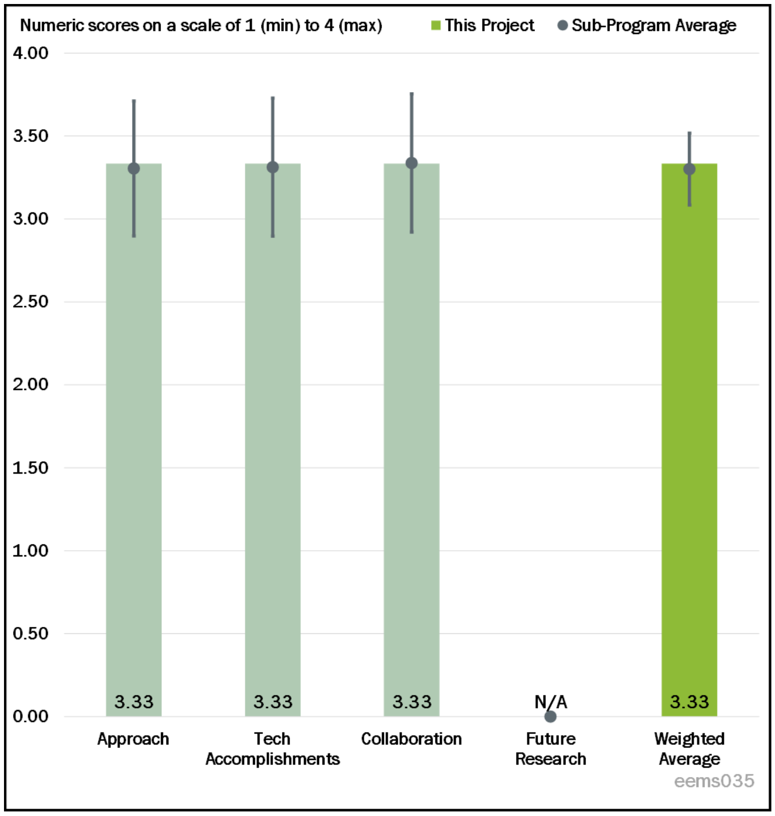

Figure 3-15 - Presentation Number: eems035 Presentation Title: Coupling Land-Use Models and Network-Flow Models Principal Investigator: Paul Wadell (University of California at Berkeley)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Urban Simulation (UrbanSim) is the only land-use model in the SMART Mobility workflow and is thus path-critical for most core models. It involves land-use change, vehicle ownership, and advanced accessibility analysis.

Reviewer 2:

Interactions between land use and mobility will be critical to understanding the energy impacts of future transportation systems. The project is a good example of interaction of models for analysis.

Reviewer 3:

This project fits well within the EEMS end-to-end modeling workflow. The project basically combines vehicle-side modeling (new forms of mobility, travel behavior, advanced charging infrastructure, traffic-flow analysis, vehicle ownership, etc.) with land-use change modeling. The project utilizes POLARIS and Behavior, Energy, Autonomy, and Mobility (BEAM) for the vehicle side, combined with UrbanSim as the land-use model, and coupled with ActivitySynth in the SMART Mobility workflow.

The project outlined three principal objectives: develop an integrated modeling pipeline that encompasses land use, travel demand, traffic assignment, and energy consumption; model combined and cumulative impacts of transportation infrastructure and land use; and improve computational performance to simulate regions over 30 years for scenario analysis. The project appears to have been well designed and targeted to overcoming specific barriers initially identified in the overview.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project has successfully completed all of the identified quarterly milestones. A number of technical accomplishments with regard to modeling have been achieved. Utilizing UrbanSim and POLARIS, this includes identification and validation of workplace choices and activity demand generation; and identification of average commute times by scenario and how this translates to changes in the built environment. Results indicate a relationship between decentralized jobs accessibility and rent job density gradients.

Technical accomplishments also include validation of activities through ActivitySim. This includes validation of departure time with the Metropolitan Transportation Commission (MTC) travel model results for work and school. Also, validation has been achieved of mode shares for mandatory and non-mandatory commute trips, commute trip distance, school choice, and auto-ownership models. Additionally, the project has demonstrated on a graphics processing unit (GPU) the ability to significantly scale performance. Simulation statistics have been developed for departure times, average speeds, and edge volumes. Finally, the project is conducting ongoing model enhancements to further improve validity with regards to real activity demand, dynamic shortest path, intersection modeling, and control inference. Significant improvements in model run times have also been achieved. In short, this reviewer observed a strong list of technical accomplishments.

Reviewer 2:
UrbanSim, coupled with BEAM and POLARIS models, showed results that closely match MTC travel model results. Workflow enhancements have significantly reduced model run times and were validated with Uber movement speed.

Reviewer 3:
The project makes good progress toward its goal of understanding the combined impacts of land use and mobility on energy use, as well as outlining continued model refinements.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project lead is LBNL and project partners include NREL, ORNL, INL, and ANL. Further collaborators include Google, Purdue University, and the MTC. Overall, the project consists of a solid and diverse set of participants for a relatively modestly funded project. The role of each partner was sufficiently identified or could be inferred from the presentation.

Reviewer 2:
The project consisted of a strong team including the five DOE SMART Consortium National Laboratory partners and collaborators, such as Google, Purdue University, and the MTC.

Reviewer 3:
No additional details on the roles taken by each of the partners were provided in the slides.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Future research focused appropriately on refining accuracy of the model.

Reviewer 2:
The project has ended, so proposed research is not applicable. However, if future activities were considered, it would be good to aggressively pursue methodologies to increase the confidence in future modeling predictions, given the extremely long-term time frames (up to 30 years) required of urban planning. During the AMR presentation, the PI discussed new technologies and approaches that are emerging that would help address the challenges of very long-term modeling predictions within the environment of a quickly evolving transportation technology landscape in the near- to mid-term. This was interesting and encouraging to hear.

Reviewer 3:
The project has ended, and no future research was discussed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is relevant to VTO objectives as linking long-term modality styles with short- and medium-term mode choice in a multi-modal transportation system (with the ability to simulate emerging mobility services) helps quantify the impact of urban development on mobility patterns and energy use.

Reviewer 2:
Yes, the project is very relevant to the EEMS goal of better understanding the impacts of emerging mobility services.

Reviewer 3:
Yes, the project is relevant because it serves to help quantify the impact of urban development on mobility patterns and energy use and the impact of SMART Mobility technologies on long term urban development. It supports the EEMS goal of linking long-term modality styles with short and medium mode choice in a multi-modal transportation system, with the ability to simulate emerging mobility services.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that $690,000 of funding for a 2-year project that involved DOE SMART Consortium National Laboratories and additional partners seems a bit low for the significance of the project scope. Because UrbanSim is the only land-use model in the SMART Mobility workflow, it is critical for most core models.

Reviewer 2:
Funding seems appropriate for such a computationally rigorous analysis.

Reviewer 3:
The resources allocated have proven sufficient to achieve the stated objectives.

Presentation Number: eems037
Presentation Title: High-Performance Computing (HPC) and Big Data Solutions for Mobility Design and Planning
Principal Investigator: Jane Macfarlane (Lawrence Berkeley National Laboratory)

Presenter

Jane Macfarlane, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

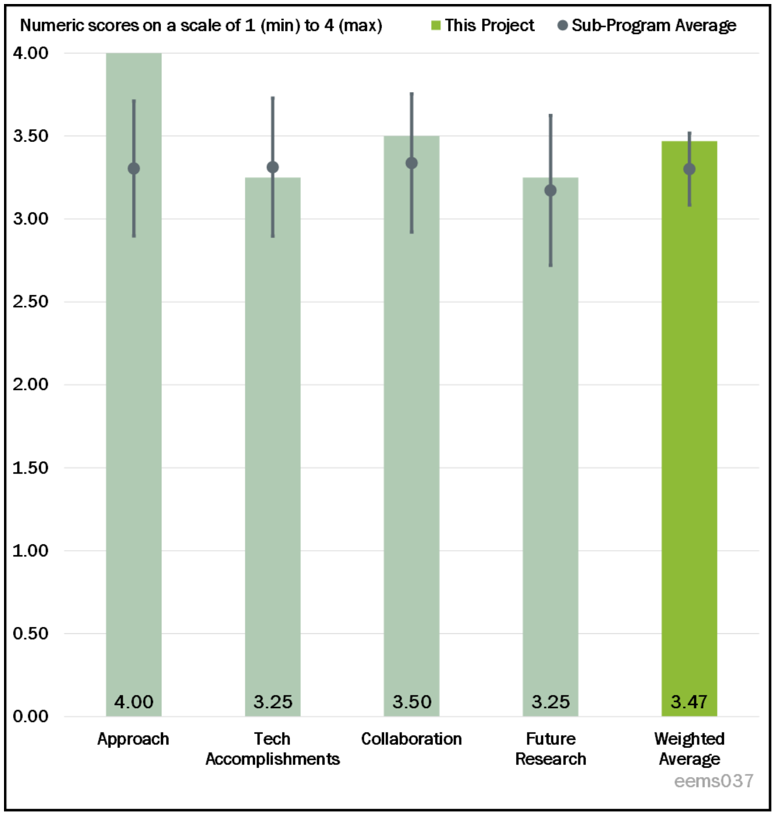

Figure 3-16 - Presentation Number: eems037 Presentation Title: High-Performance Computing (HPC) and Big Data Solutions for Mobility Design and Planning Principal Investigator: Jane Macfarlane (Lawrence Berkeley National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach is outstanding as the team has already demonstrated significant success in travel-demand modeling. Many of the traditional challenges are addressed through high performance computing (HPC), artificial intelligence (AI) and machine learning (ML) approaches that have not necessarily been perfected before. The results look promising.

Reviewer 2:

The reviewer believed the analysis was the best that could have been achieved within the sensor input source parameters and data received from live sources such as Uber. The barriers mentioned to overcome encompassed real issues and not hypothetical ones. Even the end product will be hard to fully and accurately be used in all metropolitan locations because of different limitations.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The project goal was stated as seeking an urban-scale digital twin to the real-world traffic patterns for the northern California region. It appears that the team has made significant strides toward this goal with notable progress. Therefore, the reviewer would characterize the project team's progress as excellent.

Reviewer 2:
Real-life performance indicators may have varied during the pandemic where probably fewer passenger vehicles entered the equation with the same or more heavy transport vehicles that were not part of the scenario. This would mean less traffic on city streets where cars move, and fewer cars on the interstates. The project team was still able to model those changes into the program. It should be interesting to see how everything plays out as the project wraps up in September.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
As indicated on one of the final slides, the collaboration seems to be broad and comprehensive, and results speak for themselves as evidence of strong coordination within the team.

Reviewer 2:
Judging by the list of participates, the project team had a good cross section of inputs from academia, individuals, transport companies, data suppliers, and transportation departments.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
All of the proposed future research seems reasonable. As mentioned in the question and answer (Q&A) section, data are always the issue with any project. Nonetheless, the reviewer wondered if there still might be other data out there to provide more training data and/or validation data. For example, the reviewer did not hear Waze data mentioned, despite knowing that DOT currently logs all Waze data nationwide. Perhaps there could be an additional team member and collaboration incorporating this company or other data.

Reviewer 2:
The reviewer believed that, before the change in driving habits, the project team was right on track. The team will have to change the manner in which the rest of the experiment is being conducted to figure out if the new normal that affects traffic will remain in some part, completely go back to how it was, or totally change with the vehicle makeup, which would dictate traffic flows, times, and emissions.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Clearly, this project addresses the question of transportation energy use, connectivity, and novel approaches to modeling.

Reviewer 2:
Since this project deals with mimicking traffic patterns and aims to adjust those patterns for better flow and reduced congestion—ultimately yielding to less energy use—it is relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
From the reviewer’s point of view, the resources seem well aligned with the accomplishments, team size, and future direction.

Reviewer 2:
The project team is a few months away from completing the study and is in good shape to complete it on time without requiring any more outside assistance.

Presentation Number: eems038
Presentation Title: Charging and Repositioning Decision Making for Fully Automated Ride-Hailing Fleet
Principal Investigator: Zonggen Yi (Idaho National Laboratory)

Presenter

Zonggen Yi, Idaho National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

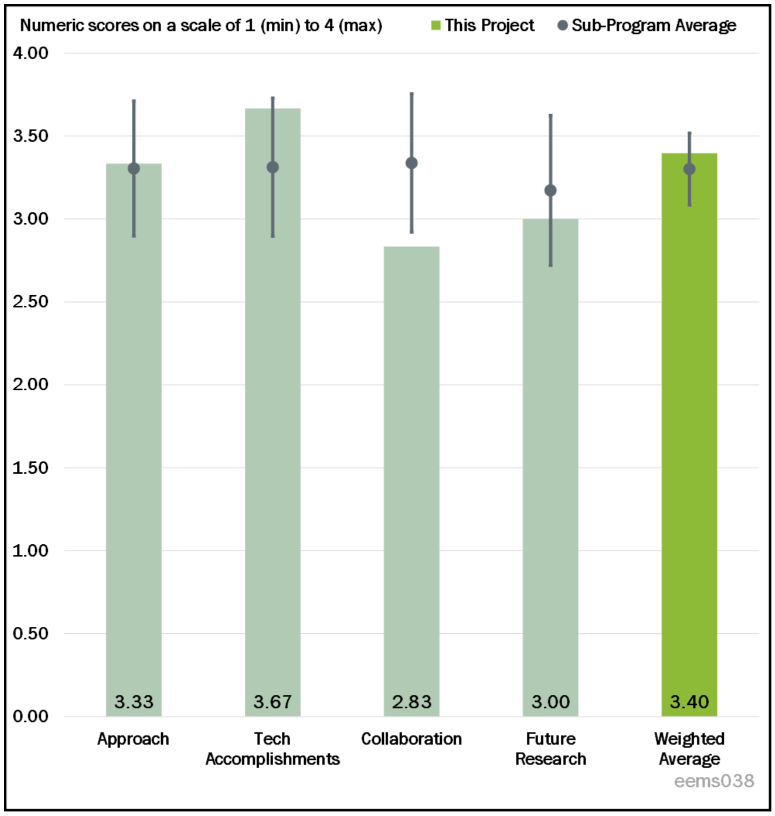

Figure 3-17 - Presentation Number: eems038 Presentation Title: Charging and Repositioning Decision Making for Fully Automated Ride-Hailing Fleet Principal Investigator: Zonggen Yi (Idaho National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project is very impressive in the amount of work that was done for only $100,000. The objective was specific, and the chosen real-world program provided the data required to complete the program. For many, this is a barrier that is never overcome. An optimized dispatch system was also developed for the New York data set. Similar scopes of work have taken longer and been substantially more costly.

Reviewer 2:

This project investigated two different models for autonomous electric vehicle (AEV) fleet operation (charging and ride-hailing). The systematic optimization approach considered all vehicles, ride requests, and chargers in the New York City area. Multiple criteria were applied to choose which vehicles to reposition in which areas and whether and where to charge. The heuristic approach assumed each vehicle independently decides whether and where to reposition and charge. Using today's New York City charging network of level 2 (L2) and direct-current fast charging (DCFC) seems unrealistic as significant AEV deployment would most certainly require a significant number of additional chargers in specific locations to serve an AEV fleet ranging from 500 to 4,000 vehicles.

Reviewer 3:

The project provides a nice approach for evaluating future AEV fleet management with regard to ride-hailing service performance and necessary charging for providing that service using two disparate AEV control methodologies. The approach developed a framework for evaluating system-level versus basic heuristic AEV fleet management methods, as well as some insights about their effectiveness when applied in major urban settings like New York City.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
For a fleet of 1,750 ride-hailing AEVs, optimization-based, centralized fleet management would result in 14% more ride requests satisfied and 43% fewer zero-occupancy miles traveled than if AEVs make independent decisions based on a heuristic strategy. To satisfy 90% of ride requests, an AEV taxi fleet using a heuristic strategy needs 15% more vehicles than a centrally and optimally controlled fleet. The smaller, centrally controlled fleet also drives 19% fewer empty miles. DCFC is essential for either scenario.

Reviewer 2:
The project succeeded in meeting its objectives of developing two methods for managing the ride-hailing service and charging requirements for AEV fleets; employing those methods in a New York City-based simulation; and quantifying their benefits from a ride-hailing service and effective charging basis. All project milestones were achieved within the proposed 1-year timeframe. The New York City simulation results indicated that the optimized system-level method generally offered significant advantages over the heuristic method for the AEV ride-hailing fleet sizes that were considered.

Reviewer 3:
The program was completed on schedule in 1 year and the objectives were met.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This project was part of the Advanced Fueling Infrastructure (AFI) pillar. No specific collaborators were mentioned, but the project length was only 1 year with $100,000 of funding. Assumptions and methodologies were coordinated with EEMS039.

Reviewer 2:
The reviewer commented that this was a difficult category, as there was little collaboration in the program by design. However, none was necessary to complete the program, so it is unfair to lower the rating for that. The singular focus at INL was probably also a major contributor to the amount of work that was completed in just 1 year and the low cost to accomplish it. While the reviewer cannot rate collaboration as excellent, as it has no collaboration, the project was designed to move without significant collaboration and was successful.

Reviewer 3:
No direct collaboration with other organizations was presented by the researcher. The researcher did collaborate with another INL investigator—EEMS039—with a similar research scope to share assumptions and methodologies, but no significant details on this coordination were presented with regard to the project. For future work, the research may solicit input from TNCs for possible insights on current and future AEV fleet management.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The project has ended. Several future research recommendations have been made, including a study on how to manage high-mileage EV driving and charging to maximize vehicle and battery life.

Reviewer 2:
Although this 1-year project has been completed, the researcher offered several future-related research topics, including expansion of dynamic control algorithms for adapting to changing grid and traffic conditions, system-level predictive capabilities, and management of AEVs for optimizing vehicle and battery lifetimes.

Reviewer 3:
Not applicable was indicated by this reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Fleet management and charging strategies for an autonomous EV fleet are directly relevant to future transportation systems and their impact on energy use (including petroleum reduction) and emissions.

Reviewer 2:
The project has quantified the effect of more rapidly charging AEVs and the benefits of an active optimization of ride-hailing management. These both provide a runway for early application of AEVs in ride-hailing services, which is a DOE objective.

Reviewer 3:
This project is relevant to DOE's EEMS program in that it researches the nexus of automated ride-hailing vehicle fleet management and productivity and electric infrastructure charging and availability.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Significant work was accomplished in a short period and for little cost. The reviewer exclaimed more of this kind of success is needed!

Reviewer 2:
The project was a "quick look"-type of a project with only $100,000 of funding over a 1-year period, which is a good, brief investment to understand the significance of the opportunity that AEVs present.

Reviewer 3:
The funding for this project seems sufficient for a 1-year project and for the technical accomplishments presented.

Presentation Number: eems039
Presentation Title: Charging Infrastructure Design Tradeoffs for a Fleet of Human-Driven and Fully Automated Electric Vehicles in San Francisco
Principal Investigator: John Smart (Idaho National Laboratory)

Presenter

John Smart, Idaho National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

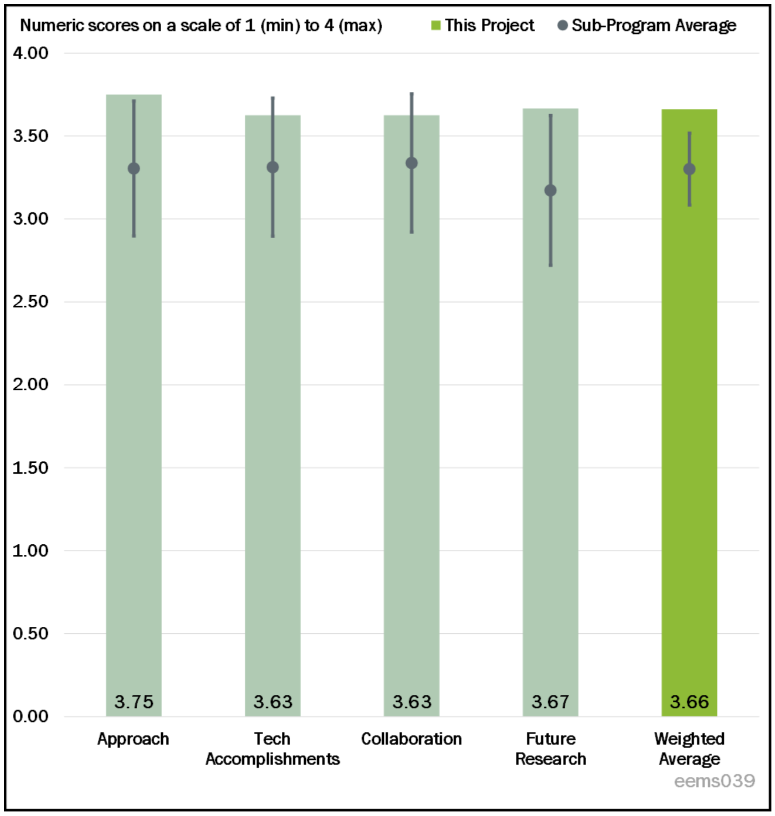

Figure 3-18 - Presentation Number: eems039 Presentation Title: Charging Infrastructure Design Tradeoffs for a Fleet of Human-Driven and Fully Automated Electric Vehicles in San Francisco Principal Investigator: John Smart (Idaho National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
Nicely done project.

Reviewer 2:
At its onset, the project was faced with a wide range of potential areas of investigation. The scope of the project was sufficiently focused to enable analyses to result in useful conclusions.

Reviewer 3:
The PI and project team have presented a well-designed project and conducted the work to completion.

Reviewer 4:
This is a really good problem and the reviewer looked forward to future work. The reviewer noted the classic chicken-or-the-egg of cars or infrastructure, and more specifically, asked how much of each and where. The team had a solid approach to kicking off these efforts, which the reviewer expected will continue with more funds.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The team delivered a very good presentation, and the reviewer mentioned it is sad to see this project ending.

Reviewer 2:
The project is complete and has generated very useful results, including insight into the impacts of sparse charging infrastructure and the cost impacts of richer infrastructures.

Reviewer 3:
The project has been completed, and all project deliverables have been met.

Reviewer 4:
Good use of graphics. It is obvious that showing the analysis results for stakeholder understanding was important to the team. All were helpful in sharing the key conclusions, particularly the building ones starting on Slide 16. The challenge in the green box on Slide 22 seemed a bit challenging and could be off-putting. While probably not intended, the reviewer suggested being careful as all stakeholders need to be engaged rather than disengaged, which can occur too easily. The reviewer emphatically praised the good work here.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Excellent project coordination between INL, LBNL, ANL, and NREL. DOE should ensure that more projects feature this kind of integrated, multi-laboratory coordination.

Reviewer 2:
The project utilized resources from LBNL, INL, ANL, and NREL, which were coordinated in the Smart Mobility Consortium, to complete work tasks.

Reviewer 3:
Seemingly good leverage was noted by this reviewer.

Reviewer 4:
The reviewer described collaboration and coordination across the project team as excellent for the defined partners, and believed that projects like this could very much benefit from an industry advisory committee. Why does that not seem to be an option on these projects? The reviewer believed there would be interested parties to do this at no cost and a line on confidentiality could be drawn. Perhaps this could be suggested for a future project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The project is tackling relevant questions and offering quantitative, easily transferable results.

Reviewer 2:
In the “future research” section, the PI and team accurately captured what the reviewer was thinking throughout the presentation, which was how to expand this more generally so that other urban population centers can conduct this analysis in a cost effective way. Future work should also consider the costs associated with any detrimental effects to TNC vehicles due to rapid charge and discharge of the battery (e.g., battery degradation).

Reviewer 3:
The reviewer understood that, at this point, the project team is suggesting industry validation. As stated previously, the reviewer thought this would be easier if a bit of industry involvement occurred earlier. The reviewer appreciated the consideration and liked bringing in level-of-service targets, which came up in a few earlier evaluator questions.

Reviewer 4:
Not applicable was indicated by this reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Charging infrastructure availability is integral to transportation electrification. Understanding the placement and the quantity of charging infrastructure, particularly in the early stages of transportation electrification, is key to supporting transportation electrification. This project provides initial insights into the quantity and cost of the required infrastructure.

Reviewer 2:
Understanding the cost-benefit analysis tradeoffs associated with building more charging infrastructure compared to larger battery sizes is valuable for TNC expansion.

Reviewer 3:
The project is very relevant to the current shared economy.

Reviewer 4:
The project is very relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project was completed on schedule and produced excellent results. This is indicative that the resources were sufficient.

Reviewer 2:
The resources appear sufficient across the project team.

Reviewer 3:
The project resources were good.

Reviewer 4:
This reviewer reported that the project ended.

Presentation Number: eems040
Presentation Title: Dynamic Wireless Power Transfer Feasibility
Principal Investigator: Omer Onar (Oak Ridge National Laboratory)

Presenter

Omer Onar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

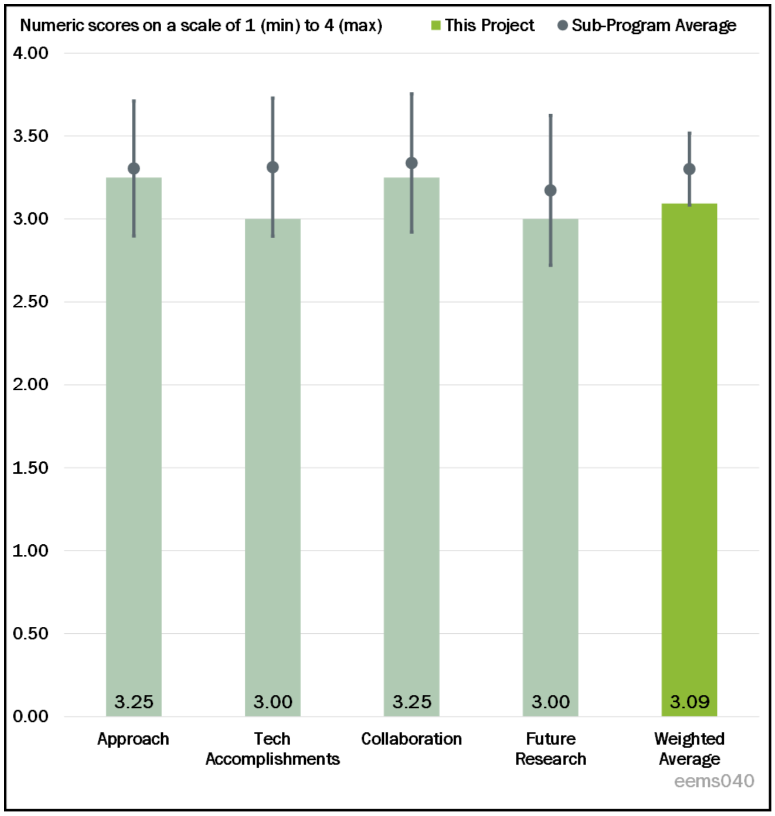

Figure 3-19 - Presentation Number: eems040 Presentation Title: Dynamic Wireless Power Transfer Feasibility Principal Investigator: Omer Onar (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project both developed an optimization technique and applied it to a specific purpose. With the vast number of factors that can impact the feasibility of dynamic wireless power transfer (DWPT), let alone its optimization, the analysis of specific applications appears to provide the greatest value for determining the value of DWPT. Otherwise, this appears to be a solution in search of a problem.

Reviewer 2:

The sound modeling approach includes characterizing vehicle energy consumption for CAVs; creating an optimal framework for sizing and placement of DWPT segments; estimating grid requirements; and validating with real-world data from M-City.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The stated technical accomplishments of evaluating vehicle energy consumption levels and DWPT system requirements, in addition to grid infrastructure requirements, is well received. A scheme for implementing in-route DWPT has been worked out and suggests that a fully automated system can be realized with charge-sustaining operation and unlimited range. The reviewer exclaimed this is very impressive and would allow a dramatic reduction in battery sizing.

An additional key finding is that with 8%-12% of route coverage using 200-250 kilowatt (kW) DWPT, charge-sustaining operation can be maintained at 70 miles per hour (mph).

Reviewer 2:
The analysis of the Arma shuttle to demonstrate the optimization techniques was a significant accomplishment. However, the results were rather qualitative and should have been reduced to a common cost denominator.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The inter-laboratory coordination was evident, but interface with the M-City Arma shuttle was excellent and key to achieving the technical results.

Reviewer 2:
Collaborations with INL have gone well.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Although the project is complete, a subsequent effort could be focused on real-world verification of the proposed schemes from the present effort.

Reviewer 2:
Not applicable was indicated by this reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project fully supports DOE EEMS's stated objectives of minimizing energy use via CAVs with reduced mass, cost, and onboard energy storage.

Reviewer 2:
Unfortunately, the response choice here is bi-stable. The reviewer indicated yes because this project has demonstrated the DWPT concept; currently, it does not have quantifiable benefits outside of a specific application. The reviewer would consider future work as not supporting DOE objectives unless tied to solving an issue with a specific application.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project completed its milestones on schedule and is currently complete.

Reviewer 2:
The FY 2019 funding of $235,000 was adequate.

Presentation Number: eems041
Presentation Title: ANL Core Tools—Hardware
Principal Investigator: Kevin Stutenberg (Argonne National Laboratory)

Presenter

Kevin Stutenberg, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

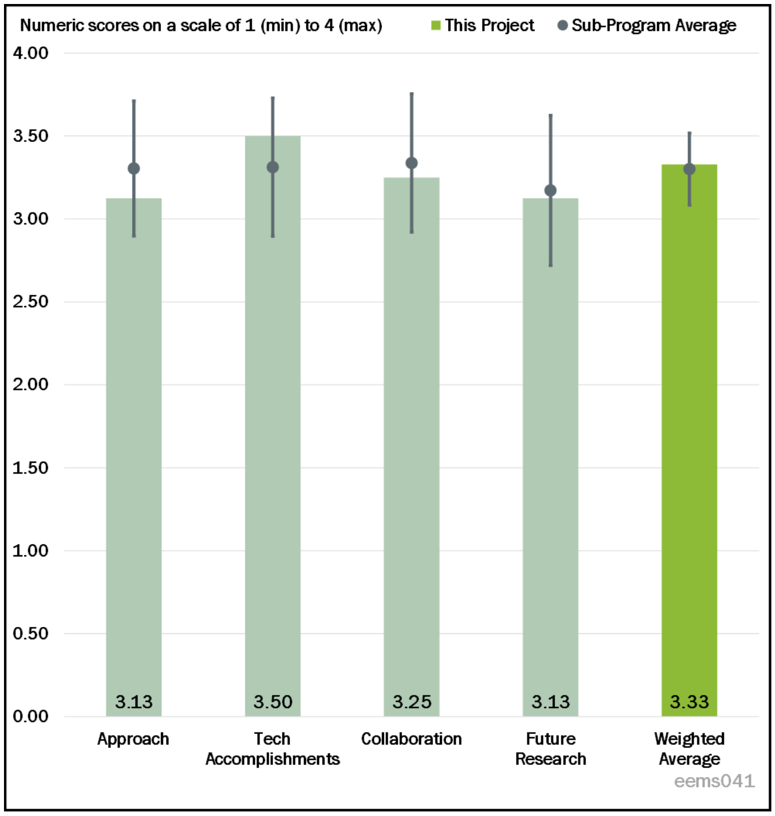

Figure 3-20 - Presentation Number: eems041 Presentation Title: ANL Core Tools—Hardware Principal Investigator: Kevin Stutenberg (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The investigators do a great job of making do with what is available and have come up with ingenious workarounds to answer the posed questions.

Reviewer 2:

Overall, the project is doing a solid job of advancing the work.

Reviewer 3:

The approach to quantifying the benefits of CAVs by creating unique, versatile hardware and software tools as part of this project is very sound.

Reviewer 4:

The vehicle-in-the-loop (VIL) approach adds credibility to the modeling results of impacts of CAV technologies.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Progress has been generally excellent. The VIL work is outstanding, and the on-the-road aerodynamic work is interesting and valuable.

Reviewer 2:
Technical accomplishments—creating and calibrating the VIL system as well as quantifying the effects of platooning, aerodynamics, driver models, accessory loads, etc.—provide an excellent foundation for MEP calculations.

Reviewer 3:
The team seems to have made solid progress over the last year.

Reviewer 4:
Additional clarity on the true project objective will help. There are way too many combinations of vehicle types, orders, chains, and condition, to simulate them all; this is complicated by continuously changing vehicles on the road. Given this, the reviewer wondered if the real objective is to understand generalized conditions. If not, better articulation of the objectives and what can realistically be developed and show output will help align the output with the objectives.

The other primary question the reviewer had is that if there is no standard method for CAVs, then how does the work extend? The reviewer would like the team to explain further and in greater detail in future documentation.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Partnerships provide the appropriate data required for the research, and an excellent effort was achieved in making the collected data publicly available.

Reviewer 2:
Collaboration and coordination with EcoCAR, NHTSA, Wayne State University, Clemson University, Michigan Technological University, etc., are well executed.

Reviewer 3:
This type of collaboration is not always easy, but the project seems to be doing a solid job in engaging and ensuring communication and input across the range of partners. This should remain an important focus of the project management, and the value is very dependent on the coordination and transfer of information.

Reviewer 4:
Collaboration exists, but it is still unclear who would be the transition partners.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future research appropriately extends the work that has been done to date.

Reviewer 2:
Planned future work on expansion of the VIL capabilities with connectivity, driver-in-the-loop, additional powertrains, as well as additional aerodynamics cases will widen the span of the project research findings.

Reviewer 3:
The plan seems logical, but the value of the proposed future research could be better articulated.

Reviewer 4:
This reviewer had nothing to add.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project provides data for other DOE VTO projects, which improve the quality of the results of those projects.

Reviewer 2:
This project strongly supports DOE EEMS's stated objective of investigating a possible reduction of transportation energy use via CAVs.

Reviewer 3:
This project contributes to the understanding of energy savings from CAV technologies in vehicle operations.

Reviewer 4:
The current work appears to meet DOE objectives. For this to remain the case in the future as the project nears completion, the researchers will need to distill and generalize the findings in a useful and actionable way. Otherwise, it will primarily end up as an academic exercise.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The FY 2020 budget of $750,000 is adequate to complete the target deliverables.

Reviewer 2:
The project is sufficiently funded.

Reviewer 3:
Resources are adequate. However, some state-of-the-art vehicles are not covered by this work. It seems additional resources might be required to cover the rapidly evolving vehicle space.

Reviewer 4:
While the researchers note the potential need for additional resources, the reviewer believed the resources are sufficient to continue progress along the proposed schedule and meet the objectives if work remains properly focused.

Presentation Number: eems044
Presentation Title: Quantification of National Energy Impacts of Electrified Shared Mobility with Infrastructure Support
Principal Investigator: Joann Zhou (Argonne National Laboratory)

Presenter

Joann Zhou, Argonne National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

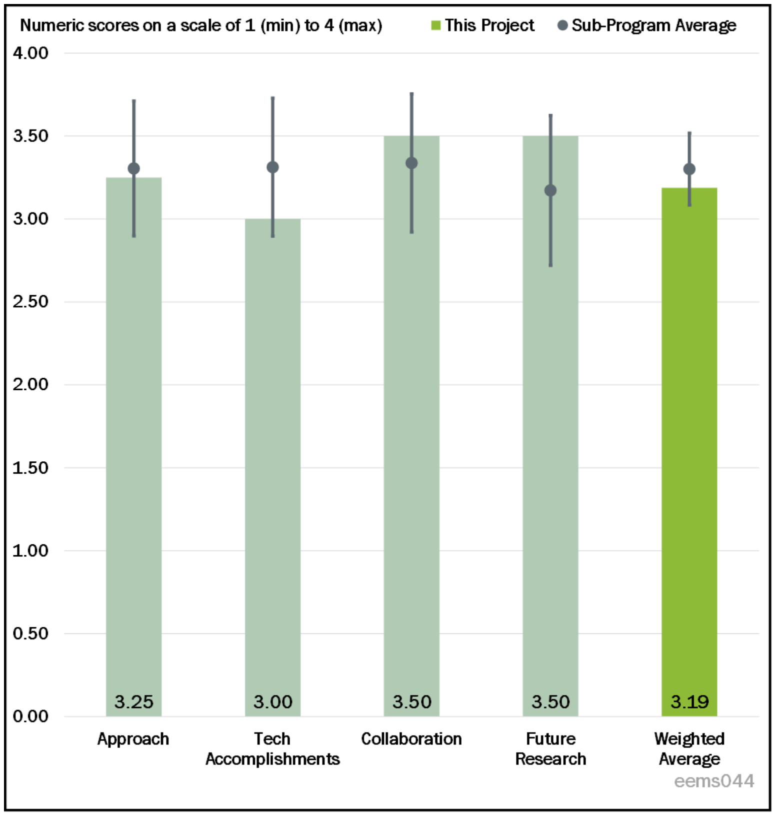

Figure 3-21 - Presentation Number: eems044 Presentation Title: Quantification of National Energy Impacts of Electrified Shared Mobility with Infrastructure Support Principal Investigator: Joann Zhou (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Comments from previous reviews point out that the project has substantial uncertainties due to lack of data, models that were used, and impacts of factors that were not considered in the analysis. While this should have been anticipated during the project's inception, the team did a good job of trying varied analytical approaches (top down versus bottom up) to try to bring clarity to the results. The development of this analytical framework provides a foundation for future work defining the usefulness of electrifying ride hailing.

Reviewer 2:

The approach to performing the work and addressing barriers is well designed. In future work, the PI should consider including a diversity of DCFC types, including those above 50 kW (up to 350 kW).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The PI has completed all deliverables as planned.

Reviewer 2:

The project is complete and has provided some quantification of the impacts of electrifying ride hailing and the effects of battery electric vehicle (BEV) penetration and charging availability. However, the results have sufficient uncertainty that they are only useful to confirm what one would intuitively anticipate: more chargers and more EVs will save more fuel. The exploration of multiple methods of quantifying national energy impacts has significant value for guiding future work.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Coordination between ANL, NREL, and ORNL has been significant while conducting the project work.

Reviewer 2:
The project has solid partnerships across ANL, ORNL, and NREL. Now that the project is complete, the PI should work with DOE to communicate the project results to the shared mobility industry and request feedback for future research in this arena.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer indicated that the project has ended and suggested that the PI consider social equity in future research in shared mobility, especially when considering the value of electric utility support in growing charging infrastructure for shared mobility programs for limited income populations.

Reviewer 2:
Not applicable was indicated by this reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Understanding how transportation electrification can impact national energy use is clearly supportive of DOE objectives. While the objective of providing quantification of this impact was not fully met, the development of an analytical framework for future projects supports DOE efforts to fully understand and quantify the impacts of transportation electrification on national energy use.

Reviewer 2:
Accurately measuring system-wide transportation impacts of AFI supporting shared mobility is timely and relevant to DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Milestones were met, evidencing that sufficient resources were available.

Reviewer 2:
Time and financial resources were efficient to complete the project.

Presentation Number: eems045
Presentation Title: Focused Validation and Data Collection to SMART Activities
Principal Investigator: Eric Rask (Argonne National Laboratory)

Presenter
Eric Rask, Argonne National Laboratory

Reviewer Sample Size
A total of two reviewers evaluated this project.

Project Relevance and Resources
100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

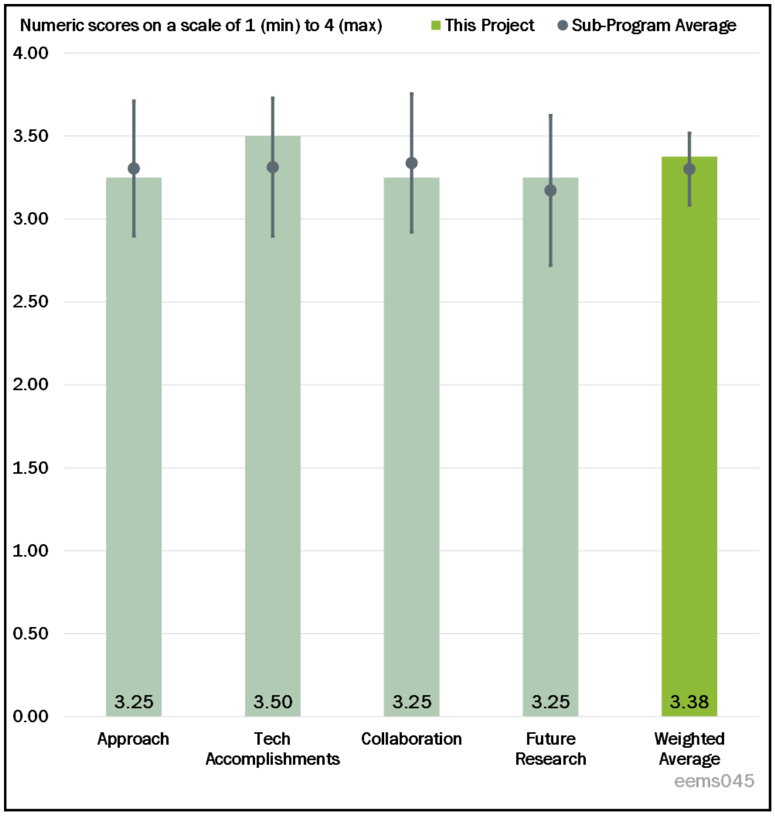

Figure 3-22 - Presentation Number: eems045 Presentation Title: Focused Validation and Data Collection to SMART Activities Principal Investigator: Eric Rask (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The team did very good work in designing the project to achieve maximum results with limited resources and a somewhat open-ended subject since CAVs are emerging technology.

Reviewer 2:
As the PI mentioned, this was a first “nibble” in this area and an important one according to the reviewer. It is challenging to have two projects within one. Color coding the presentation was a good idea for this reviewer’s understanding.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Important results have been obtained that help to clarify inputs for other projects (e.g., power consumption of a vehicle sensor suite). The team did good work on the automated shuttle, another emerging technology option.

Reviewer 2:
Activities completed matched the goals of the project’s broad description. The team has brought to the forefront the sensing and computing loads that are significant and likely underappreciated before this work. Future work should more explicitly estimate the options going forward to mitigate these loads (e.g., the situation today is x, but improvements can reduce the power demand to y in the future).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The listed partners are helpful in providing either data and/or hardware needed for achieving the project goals.

Reviewer 2:
Evidence presented showed good collaboration across the labs, but the reviewer believed more involvement by industry would have helped. Could there have been some sort of industry advisory committee for this project? Is that done with DOE projects? Should it be? Maybe such a committee could meet only once or twice per year.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Future work continues and extends the existing project work. A bit more detail would be helpful.

Reviewer 2:
The reviewer believed proposed future work was missing in the review. As this first nibble, this team should have proposed a much longer and deeper list of suggestions for future work.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Knowledge and data gained from this project are used to inform other DOE VTO project work.

Reviewer 2:
The reviewer responded that, absolutely, there are oftentimes adverse consequences and power demand for the new technology is clearly one.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project is working well with the existing resources. However, more funding would be beneficial in expanding the vehicles available for study, particularly as more OEMs produce L2 and L3 capable vehicles.

Reviewer 2:
The project resources are sufficient.

Presentation Number: eems057
Presentation Title: Urban Traveler–Changes and Impacts: Mobility Energy Productivity (MEP) Metric
Principal Investigator: Venu Garikapati (National Renewable Energy Laboratory)

Presenter

Venu Garikapati, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

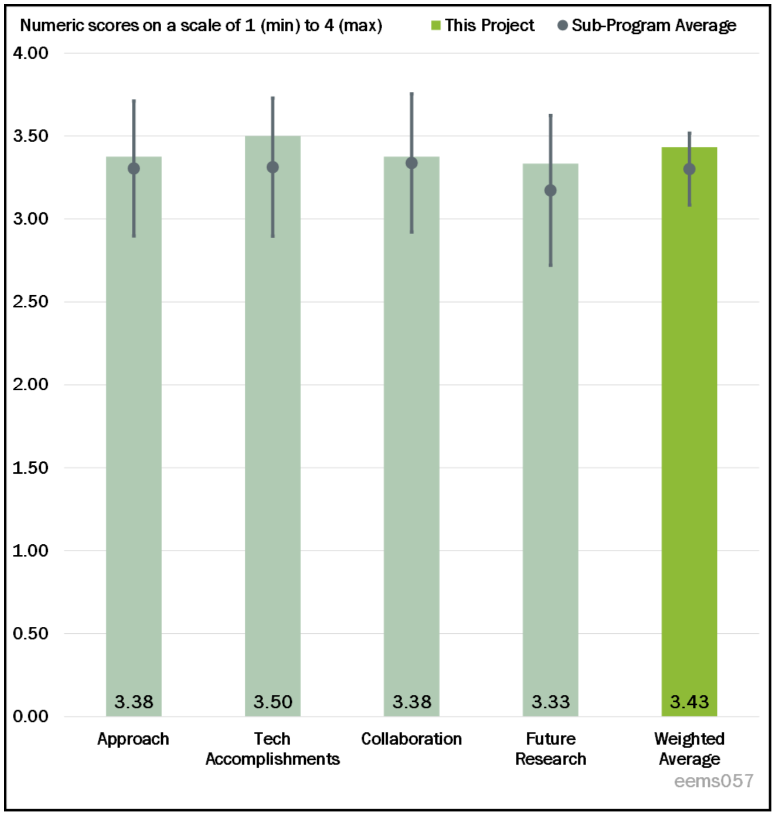

Figure 3-23 - Presentation Number: eems057 Presentation Title: Urban Traveler–Changes and Impacts: Mobility Energy Productivity (MEP) Metric Principal Investigator: Venu Garikapati (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The approach seemed sound for this MEP-focused project.

Reviewer 2:
The design of the project has been greatly enhanced by addressing the concerns of the previous review. It is feasible, and technical barriers have been addressed.

Reviewer 3:
The project clearly addresses the need to establish a practical metric to quantify MEP and design integration of the value into other models evaluating travel behavior, autonomous vehicles, and regional planning carried out by National Laboratories and regional planning agencies. The capability to illustrate results in a geo-spatial display makes the metric more useful and understandable in comparative analyses.

Reviewer 4:
The model has potential as a useful framework for performing scenario analyses for policy development. However, urban policy generally focuses on improving quality-of-life factors, such as air quality, safety, and noise, none of which is addressed in the model (but likely correlate with it). Also, the relative value of renewables should be weighted with a premium in parts of the country where the grid is comprised of greater renewable electricity.

The model also does not propose a metric for robustness of each mode. The number of the assumptions varies considerably within each transport mode; the benefits of some modes, perhaps such as walking, have a narrow range of assumptions. Transport by private cars, ride sharing, and CAVs has a broad range of assumptions. Particularly when a disruptive event like COVID-19 comes into play, it suggests the importance of a robust metric for sustainability and/or resilience. This tool could likely address such questions, but presently does not.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project exhibited success in generating energy productivity scores for 50 top metropolitan areas in the United States, although it appears this met half of the 100-city goal. This success still provides a baseline to compare the impact of future actions initiated by cities and regional planning organizations. The deep-dive analysis provided greater insights than expected. It is good to see MPOs picking up the tool to use in regional planning.

Reviewer 2:
According to the reviewer, good progress and findings have been made to date. The fact that several municipalities are considering utilizing MEP tool shows success and validity.

Reviewer 3:
The application of the tool to many cities in the United States demonstrates good progress. Further work is needed to develop MEP models for emerging trends in micro-mobility and teleworking.

Reviewer 4:
Overall, the technical accomplishments and progress were excellent (and actually wrapping up). The main concern or at least question about MEP as a metric is around what difference in MEP for a given scenario is statistically significant, producing a real and noticeable change to the transportation system? While MEP is clearly useful qualitatively and directionally, it is not clear if it is worth pursuing a different scenario from the baseline for an MPO for a MEP difference of x, for example.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project displayed an outstanding effort to integrate energy productivity with the BEAM and POLARIS models and the SMART Mobility Team with input and collaboration with industry partners.

Reviewer 2:
The outreach to various MPOs, Transportation Planning Organizations (TPOs), and state DOTs is especially impressive and worth promoting further.

Reviewer 3:
Overall, the collaboration seemed fine, but it also seemed like the collaboration should have included DOT in the research team.

Reviewer 4:
Collaboration across the project team was hard to discern in the presentation. It was not totally clear who was doing what. The partners are excellent and diverse, but there needed to be a slide and discussion on division of tasks.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
While this project is finished for now, the future research suggestions is nonetheless useful and on point.

Reviewer 2:
Proposed future research was very well defined but may need to change due to COVID-19 and other disruptors. It does seem that the algorithm will allow this to be included.

Reviewer 3:
The project ended.

Reviewer 4:
The proposed follow-up research is reasonable. Given the impact of COVID-19 on travel demand and the related economic downturn, it might be worth adding an income and wealth dimension to the model that provides insights about impacts on disadvantaged communities. Also, it might be worth modeling the impact of telecommuting and work-at-home trends spurred by COVID-19 and comparing energy productivity by adopting a more integrated intercity rail, subway, surface tram, and bicycling “what if” scenario as seen in several European cities.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Multi-modality is vital. With this addition, the project is quite valid.

Reviewer 2:
The project is definitely relevant to DOE objectives, though the only concern is ensuring there is not duplicative efforts with other projects.

Reviewer 3:
The MEP project supports DOE’s current objectives.

Reviewer 4:
The project advances and is consistent with DOE goals to improve the energy productivity evaluation of a future integrated mobility system.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
A significant amount of work seems to have happened, given the (now complete) funding for this project.

Reviewer 2:
The funding and resources have been sufficient to successfully achieve the project goals.

Reviewer 3:
Resources appear to be fine, but the role of each needs clarification.

Reviewer 4:
The project was completed on schedule even though additional cities could have been added in a comparative analysis.

Presentation Number: eems058
Presentation Title: Systems and Modeling for Accelerated Research in Transportation (SMART) Mobility Consortium Tools and Process Development
Principal Investigator: Aymeric Rousseau (Argonne National Laboratory)

Presenter

Aymeric Rousseau, Argonne National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

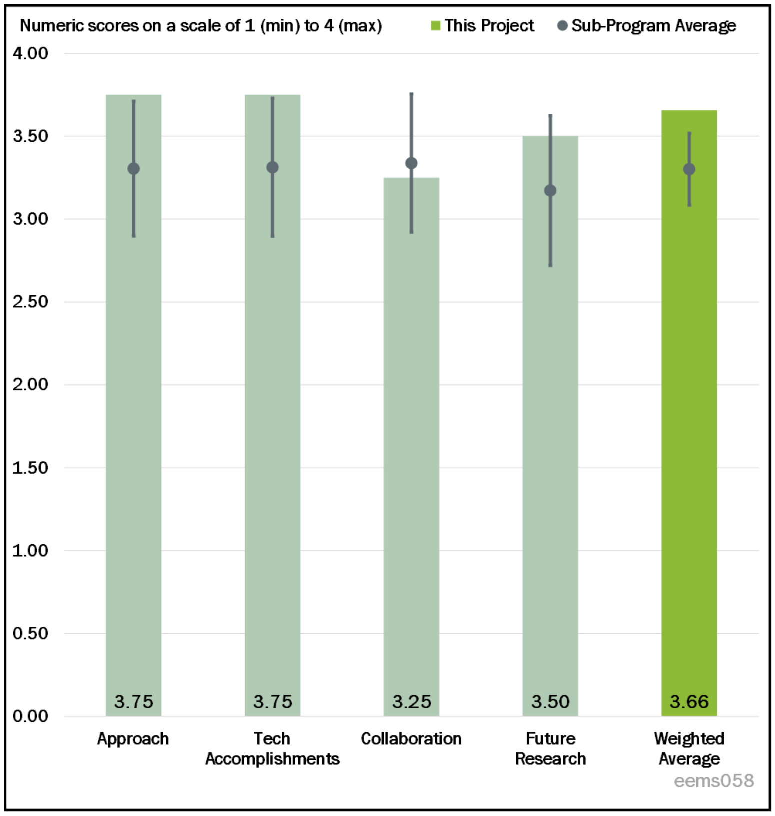

Figure 3-24 - Figure 3 24 - Presentation Number: eems058 Presentation Title: Systems and Modeling for Accelerated Research in Transportation (SMART) Mobility Consortium Tools and Process Development Principal Investigator: Aymeric Rousseau (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The overall approach is outstanding, including the incorporation of HPC on top of a POLARIS model (that can run efficiently on a desktop) to produce much more powerful, numerous, and comprehensive results.

Reviewer 2:
The approach is comprehensive in addressing the barriers.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The overall technical accomplishments and progress (now wrapping up) were outstanding. One noted as positive was the POLARIS codebase being in C++ rather than built upon a bloated, modular coding system. This clearly is perhaps an unsung hero in this model, allowing for 4-6 hours of runtime for 10 million agents as a basis upon which HPC can take over and create a far deeper and a broader dive into the modeling space. It also should be noted that the validation of POLARIS is no small feat and truly positions that model for a strong future.

Reviewer 2:
The team has made solid progress.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration on this project appears to be strong and excellent, with multiple diverse partners having useful perspectives.

Reviewer 2:
There is plenty of collaboration, but the complex team structure may also pose logistical challenges in coordination.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
While the funding is ending for this particular project, the future research proposals were solid and useful to use for scoping next steps. The one area not discussed (at least the reviewer did not think it was discussed) was utilizing this system for real-time, operational support in addition to scenario simulations. The reviewer had the sense that there may be some opportunities here.

Reviewer 2:
The project has ended.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Clearly this project builds on strong past work and is highly relevant to the DOE objectives.

Reviewer 2:
The project supports DOE objectives in understanding future scenarios, especially from the travel-demand perspective.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources seemed sufficient and produced significant deliverables for that level of funding.

Reviewer 2:
Funding was sufficient.

Presentation Number: eems059
Presentation Title: Experimental Evaluation of CACC for Passenger Cars
Principal Investigator: Xiao Lu-Yun (Lawrence Berkeley National Laboratory)

Presenter

Xiao-Yun Lu, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 33% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

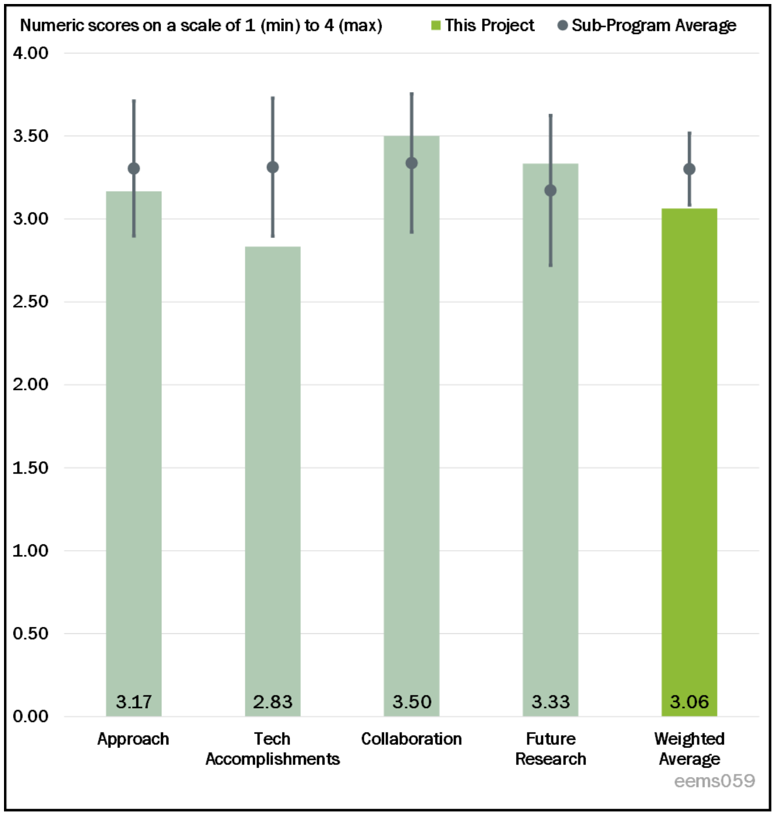

Figure 3-25 - Presentation Number: eems059 Presentation Title: Experimental Evaluation of CACC for Passenger Cars Principal Investigator: Xiao Lu-Yun (Lawrence Berkeley National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
For the given goals and the constraints involved (e.g., no automotive OEM support), the approach was sound for creating adaptive cruise control (ACC) and CACC systems of vehicles.

Reviewer 2:
The project approach was outlined in the presentation, including reference to vehicle instrumentation; developing torque mapping for control actuation; installing driver for dedicated short-range communications (DSRC) packet passing; developing vehicle dynamics modeling and CACC; control design; implementation and systems integration; developing a driver vehicle interface (DVI); preliminary test track testing; control tuning; and high-speed field testing. The presentation also specifically discussed responses to last year’s review, as well as remaining project challenges. The project seems to thoughtfully take various factors and feedback into consideration.

Reviewer 3:
More detail is needed on other barriers that CACC can address in terms of energy use in vehicles and efficiency of transportation systems.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
This project started on September 1, 2018, and is scheduled to end on July 31, 2020. The presentation noted that all milestones had experienced some initial delay. However, as of the end of April 2020, one milestone was fully accomplished and two were largely accomplished (95% and 80% progress, respectively).

Reviewer 2:
The technical accomplishments and progress were good, but perhaps could have been enhanced with a bit more application (and results) from exercising the ACC and CACC system that was developed. As part of the audience, the reviewer indicated like there was a big wind-up to creating this fascinating system to then be able to run all of these various scenarios, gather data, and present on the data. However, there was only a little bit on the application and scenario front presented.

Reviewer 3:
The reviewer expressed interest in the reasons for project delays. What are the implications for this research in the long run and how can this to full automation?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The presentation makes it clear that collaborating partners (ANL, INL, LBNL) have successfully accomplished a range of outlined achievements described in the slides. Tasks were clearly divided, and subsequent progress was successfully made. While the reviewer cannot speak specifically to the dynamics of the team's coordination mid-project, it appears that there was significant team contribution in pulling together the final output.

Reviewer 2:
The responsibilities seem fairly divided between partners.

Reviewer 3:
It was noted that previous reviewers suggested that safety be studied as part of this research, and the response to that mostly was that NHTSA was already doing this. However, the reviewer thought this missed the point. The safety and energy use of CACC are inextricably linked and cannot very effectively be segmented out to one organization performing the safety part and one organization performing the energy-impact part. In the end, CACC and platooning will either save energy and be safe, or the following distance will be too great to capture the significant savings from reduced aerodynamic losses.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
A range of future research proposals is outlined, including developing higher-level automation, vehicle-control capabilities and developing other maneuver capabilities, among other proposals (funding dependent). Specific examples are provided along with each suggestion, detailing how work could be further advanced.

Reviewer 2:
The proposed research focusing on L2 and L3 vehicle automation makes sense, as this project was an effort to document energy impacts from L3 vehicles. Doing a comparison of LD to HD energy savings from CACC applications would be worthwhile.

Reviewer 3:
The reviewer thought this type of work could have a very significant impact if continued, but to date it indicated like it was more of a setup to, than an execution of, capturing needed data and scenarios.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The objective of this project is to develop cruise control (CC), ACC, and CACC capabilities for three passenger cars with different powertrains and leveraging L1 automation on public roads. By exploring associated impacts on energy consumption and traffic flow, this project contributes to DOE's goal to support a more economically competitive, environmentally responsible, secure, and resilient U.S. energy infrastructure.

Reviewer 2:
This project is no doubt highly relevant to DOE's objectives: studying energy of a vehicle CACC system.

Reviewer 3:
This project is in line with EEMS automation research.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources were sufficient for the soon-to-end project, as the primary end points were met. Future funding would of course be needed to explore further, including the possibility of upgrading to more late-model vehicles, some of which may have some built-in functionality.

Reviewer 2:
Funding appears to have generally been sufficient. The presentation broke down funding by year—FY 2018 versus FY 2019. The presentation did note, however, that data support would be necessary for microscopic mixed traffic modeling with CAVs with different powertrains and its mobility and energy consumption evaluation.

Reviewer 3:
Given the delay in the project timeline, more funds may be needed to complete the research.

Presentation Number: eems060
Presentation Title: Agent-Based Model and Data Collection for Inter- and Intracity Freight Movement
Principal Investigator: Monique Stinson (Argonne National Laboratory)

Presenter

Monique Stinson, Argonne National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

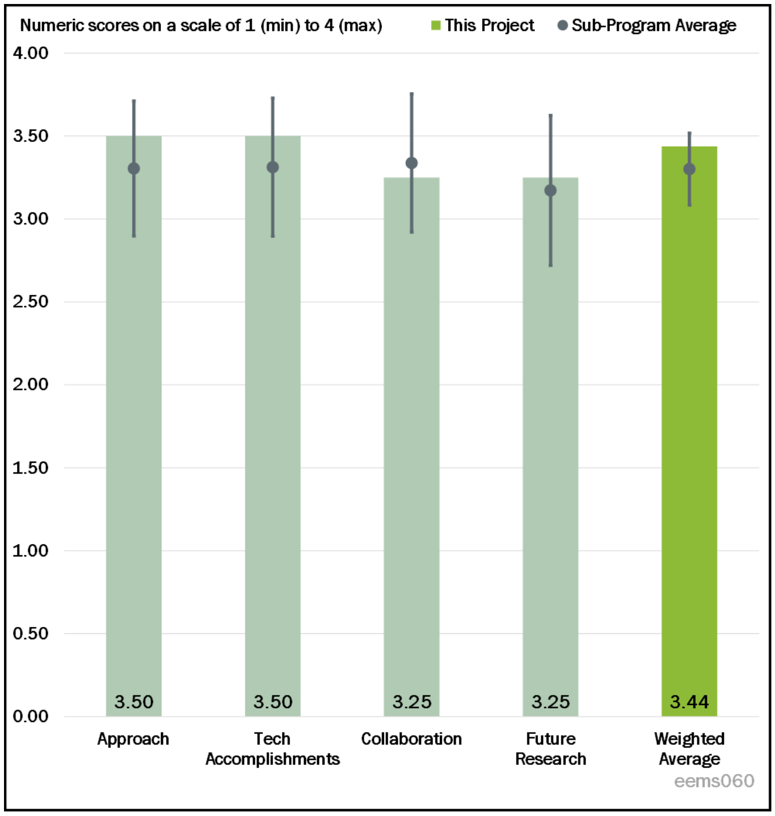

Figure 3-26 - Presentation Number: eems060 Presentation Title: Agent-Based Model and Data Collection for Inter- and Intracity Freight Movement Principal Investigator: Monique Stinson (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

There is a strong start and logical approach for creating a baseline for future research with this short project.

Reviewer 2:

The team attempts to answer the key question of how commercial and household activity has the potential to impact freight energy use and mobility.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

POLARIS is now set up for freight in a way that will scale for freight analyses, both intracity and regional.

Reviewer 2:

The project seems to be on track, but it would be interesting to understand how some of these models change, given current COVID-19 impacts. It would also be good to understand how last-mile delivery options and autonomy may change the modeling results.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The project team has good stakeholder and data representation.

Reviewer 2:
The collaboration was okay at the start of this work. However, the reviewer ended to believe projects like this could benefit from some informal work with industry and maybe even academia. Are there ways to utilize surveys or workshops to gain knowledge and needs with other companies and NGOs?

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
There is a good pretty lengthy list of future research, given the base framework created. The reviewer suggests maybe working with others, along with VTO, to prioritize these future efforts.

Reviewer 2:
Follow-up research questions seem logical, but the team is still missing an evaluation of a situation, such as the current one, where all consumption shifts to e-commerce due to lack of access to stores. It would be useful to have a comparison point, even for short-term spikes.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project very much supports the overall DOE objectives. The reviewer was glad that VTO is investing in the freight system along with the vehicle technologies themselves.

Reviewer 2:
E-commerce will have a significant impact on the frequency and method of goods delivery. Given that the impacts are still relatively unknown, this seems like an appropriate research question for DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Project resources seem appropriate for a project of this scope.

Reviewer 2:
Project resources seem sufficient, although it is difficult to really ascertain.

**Presentation Number: eems061
Presentation Title: Real-Time Data and Simulation for Optimizing Regional Mobility in the United States
Principal Investigator: Jibonananda Sanyal (Oak Ridge National Laboratory)**

Presenter

Jibonananda Sanyal, Oak Ridge National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

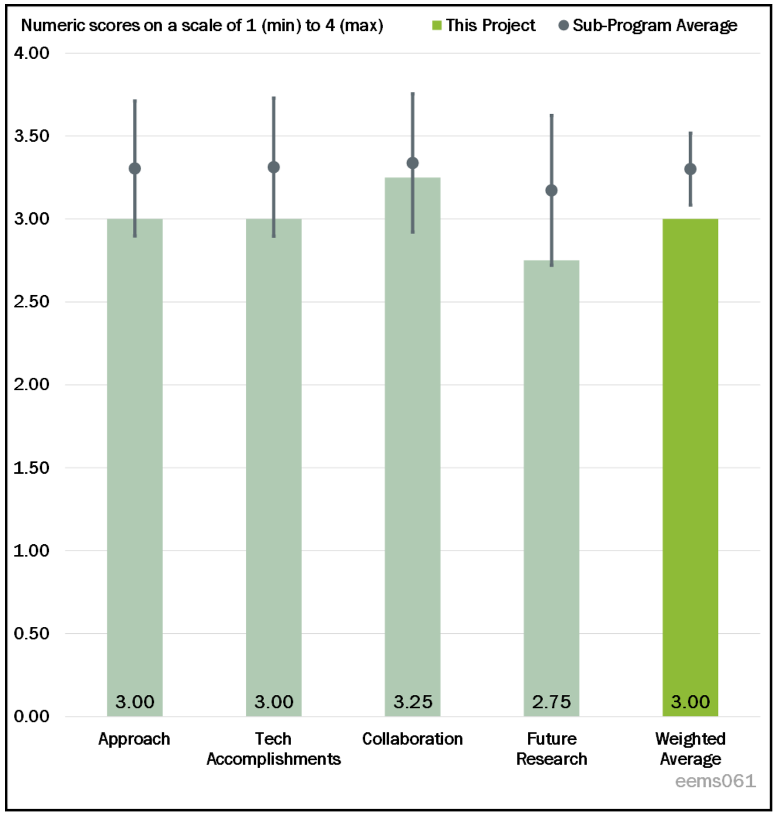

Figure 3-27 - Presentation Number: eems061 Presentation Title: Real-Time Data and Simulation for Optimizing Regional Mobility in the United States Principal Investigator: Jibonananda Sanyal (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This is an interesting and ambitious project from a technical perspective. The project used HPC to address the problem of computational complexity. This feature could be an obstacle to cities' adoption of the tool. Also, a working digital twin of a metro area used for transportation planning and operations should include all modes, not just cars and trucks.

Researchers indicated that the model does not account for induced demand or other behavioral aspects (though it does have a dynamic traffic assignment component). The extent of any induced demand could be an important determinant of the energy impacts of the control system. A simple sensitivity analysis of possible effects would be informative.

Reviewer 2:

The proposed project leaves a lack of accurate data to fill in the gaps. If the premise is reliant on good data and it is admitted the data are a little erroneous, it is tough to draw an accurate conclusion. Without freight data that are good in that corridor and that also have a high flow of tractor-trailers that are restricted to the interstate, it would be hard to do a good simulation.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
This is a technically challenging project that has had substantial accomplishments. The project has shown energy savings approaching the 20% target in certain circumstances. However, that is the target for regional savings, not single-road savings.

It would be useful to report what the control system's effect was on travel time.

Reviewer 2:
It seems that the plans and anticipated deadlines are being met. Given the pandemic, the reviewer asked whether those figures can be reflected accurately in the model where there will be a constant or rise in freight but a reduction in passenger cars?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration between ORNL and the NREL appears to have been sufficient. Non-funded partners provided data and sensors but do not seem to have participated in the research.

Reviewer 2:
There was good collaboration with the universities, DOT, and TomTom, but the reviewer wanted to know if there is another real-time entity to gather information from. One's cell phone makes real-time traffic decisions better than the one programmed in the vehicle simply because of so many constant variables.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Proposed FY 2020 research includes "energy estimates model refinement." It would be useful to include vehicle powertrain type in anticipation of a growing EV population, since these vehicles may show lower percentage savings and require different control strategies. Demonstration of CTwin portability in FY 2021 will be important.

Reviewer 2:
The reviewer thought that the future research should include information as far as Knoxville, Tennessee, to get a better idea of the different conditions. If you use this model to predict an Atlanta, Georgia, scenario, the differences are too wide a gap to do it accurately.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer believed the project team attempted to determine better traffic flow, which helps reduce idling time, energy, and, in essence, emissions for Class 8 vehicles.

Reviewer 2:
The project is focused on energy savings, supporting overall DOE objectives. However, the boundaries of the analysis may keep it from delivering a complete picture of the energy impacts of this approach.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project appears to be largely successful and on time, with no indication of insufficient resources.

Reviewer 2:
The reviewer thought the resources are sufficient but will not yield as large a swath as necessary to carry it over a large area.

Presentation Number: eems062
Presentation Title: Deep-Learning for Connected and Automated Vehicle (CAV) Development
Principal Investigator: Robert Patton (Oak Ridge National Laboratory)

Presenter

Robert Patton, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

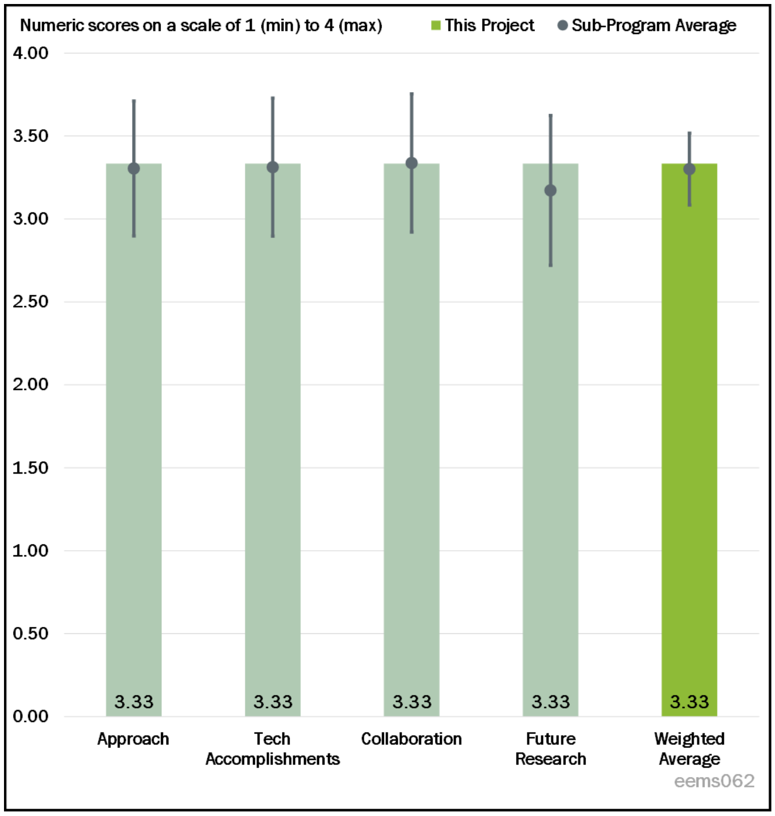

Figure 3-28 - Presentation Number: eems062 Presentation Title: Deep-Learning for Connected and Automated Vehicle (CAV) Development Principal Investigator: Robert Patton (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The team's approach to developing computational capability using HPC in order to rapidly develop perception, control, and communication algorithms for CAVs is sound.

Reviewer 2:

A clear action plan and timeline have been provided. Barriers are addressed, but there are still many unknowns in this phase.

Reviewer 3:

This project seems to focus on an end-to-end solution for camera-based autonomous driving. "CAV" in the title may be a bit confusing. So far, it is not very clear how to quantify a driver to be an expert for imitation learning. Also, it is not very clear if there would be any other side effects for the entire traffic flow (under different CAV penetration rates, including the extreme case of 100% CAVs) if autonomous driving is trained in this way.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The technical accomplishments in this project include the use of Multi-node Evolutionary Neural Networks for Deep Learning (MENNDL) for object perception; imitation learning; gathering training data for imitation learning; adversarial testing; Kroad; KFlow; and two-dimensional and three-dimensional learning transfer. Very impressive!

Reviewer 2:
According to the timeline and percentage of completed efforts, the reviewer did not have too much concern about the progress. The technical accomplishments sound reasonable.

Reviewer 3:
The team has made a good start in the analysis and scenarios, according to plan.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Since last year, the presenter has coordinated well with several key companies in this space.

Reviewer 2:
Collaboration and coordination with the NREL and General Motors (GM) are well executed.

Reviewer 3:
The involvement of GM weighs much for the project team. The reviewer expected the project team could leverage much experience and knowledge on AV (using the similar platform) from the industry, like GM (or its Cruise) in this project, although there might be some confidentiality issues.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Future research included a clear action plan, partner roles, and next steps. Roadblocks and a means to address them were well thought out.

Reviewer 2:
The integration of a game engine-based driving simulator (CARLA) and traffic simulator (e.g., Simulation for Urban Mobility [SUMO]) makes sense to the reviewer. The reviewer thought the development of such an advanced simulation and modeling platform would be an interesting research topic for further exploration.

Reviewer 3:
The list of proposed future work includes the creation of enhanced perception and control algorithms using MENNDL, improved reinforcement learning for driving simulators, and increased scenario generation.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project supports DOE EEMS's stated objective of exploring reduced transportation energy use via autonomous vehicles.

Reviewer 2:
Yes, this project should support the overall DOE objectives by leveraging the CAV modeling and control capability within DOE National Laboratories.

Reviewer 3:
The reviewer thought this will take time to figure out because the replication of the human driver in simulation is needed to then assess the energy savings.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Enough people and research partners were provided, and the focus remains, despite the economic issues in the industry at this time.

Reviewer 2:
The FY 2020 resources of $2.2 million are adequate to achieve the target deliverables.

Reviewer 3:
Again, the reviewer thought the inclusion of GM in this project should provide sufficient resources to achieve the stated milestones in a timely fashion. The only concern is how much of industry's resources can flow into this project.

Presentation Number: eems063
Presentation Title: Ubiquitous Traffic Volume Estimation through Machine-Learning Procedure Principal Investigator: Venu Garikapati (National Renewable Energy Laboratory)

Presenter

Yi Hou, National Renewable Energy Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

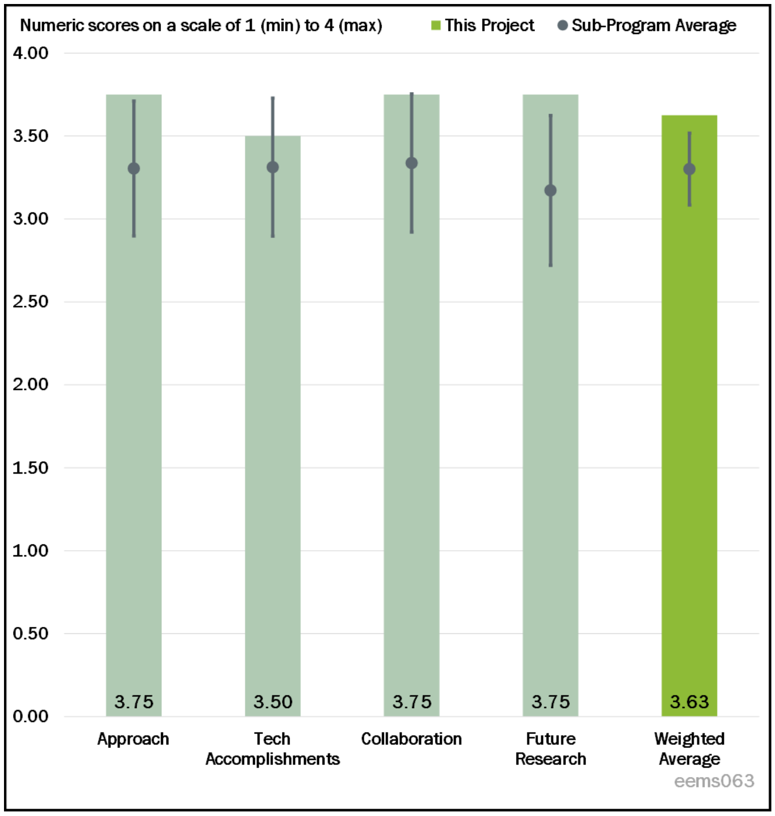

Figure 3-29 - Presentation Number: eems063 Presentation Title: Ubiquitous Traffic Volume Estimation through Machine-Learning Procedure Principal Investigator: Venu Garikapati (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project has a very clear and narrowly defined objective: commercialize a machine learning based traffic volume estimation tool with TomTom using vehicle probe data. The focus is to utilize and fuse existing high-quality yet sparse data with probe data to predict traffic volumes on each and every link of a road network.

This is essentially a product development project from concept through first product version. The project approach includes milestones tool validation; demonstration of tool prototype; detailed commercialization plan; integration of a demonstration product into the TomTom web framework; publication of validation results from real-time deployment; and delivery of a first version of the product. The project milestones seem logical and well sequenced.

The project approach includes four types of input (probe traffic data, road characteristics, weather information, and temporal information) uploaded to a ML model (XGBoost), which generates traffic volume information anytime. Four parameters have been identified to define model accuracy, including the coefficient of determination (R2); mean absolute error (MAE); weighted absolute percentage error (WAPE); and error to maximum flow ratio (EMFR). These parameters and their maximum threshold percentages were identified and developed in concert with program partners. Subsequently, the approach splits fused data into training data and test data to exercise and validate the XGBoost model. Overall, this is a very strong project concept and technical approach.

Reviewer 2:
The PI has sufficiently demonstrated that the approach has the potential to bring a first of its kind tool, in terms of level of accuracy for traffic-flow predictions, into the market.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project has demonstrated a solid list of technical accomplishments. This includes demonstrating data training of the model through testing and validation of predicted versus actual volume estimation results in freeway and off-freeway scenarios. Three geographical locations were examined: Harrisburg, Pennsylvania; North Carolina; and Chattanooga, Tennessee. Overall, model traffic volume estimation results from the first two locations were considered excellent and good, respectively. The results for Chattanooga were only considered fair, largely as a result of less robust data inputs and more significant resulting deviations from the established boundaries of a few of the model accuracy parameters. The finding here is that probe data and sensor data quality have a significant impact on volume estimation accuracy.

The traffic volume estimation tool, XGBoost, has been validated and verified by data from the aforementioned sites, and it has been demonstrated that machine learning is a powerful tool for volume estimation. XGBoost is not only able to predict recurring traffic patterns, but is also able to detect anomalies in regular patterns (e.g., an extreme weather event). The results from this project can be applied to both historical and real-time traffic volume estimations.

This 2-year project started late because of contract negotiations with TomTom, but now appears back on schedule.

Reviewer 2:
The progress and results generated thus far seem to be well on target with respect to the project plan.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This project includes an extensive group of diverse project participants—multiple state DOTs, the University of Maryland, the Texas Transportation Institute, the I-95 Corridor Coalition, and an industrial manufacturer, TomTom—with strong intra-project collaborations.

Reviewer 2:
Collaboration with partners appears to be well coordinated.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Future research appears well thought out. Development of a data-streaming pipeline and automated anomaly detection are spot-on, logical steps toward a reliable commercial tool.

Reviewer 2:
The project does an excellent job of identifying the remaining challenges and barriers, including the need for a real-time data feed, addressing different data formats, and the quality of data, which necessitates the development of a data-quality check mechanism. The proposed future research directly addresses these challenges.

Another reviewer asked how long model predictions would be valid into the future. One question that comes to mind is how much will the estimated cost be to update and periodically calibrate XGBoost to keep it sufficiently accurate and relevant moving into the future? The reviewer also asked if it were possible that this could end up being an onerous expense and potentially diminish the tool's value.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is very relevant, as it supports two of EEMS's strategic goals and has three direct applications, including enabling energy assessments, enhancing energy efficiency, and enabling accurate transportation modeling and simulation through real-world mobility data.

Reviewer 2:
Accurate traffic-flow estimation is an important piece in a bigger puzzle of designing more efficient transportation systems.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project is moderately funded by DOE ($500,000) and includes 50% cost share from TomTom, which is excellent.

Reviewer 2:
Project tasks and allocated resources seem to be aligned appropriately.

Presentation Number: eems066
Presentation Title: Livewire Data Platform–A Solution for Energy Efficient Mobility Systems (EEMS) Data Sharing
Principal Investigator: Lauren Spath Luhring (National Renewable Energy Laboratory)

Presenter

Lauren Spath Luhring, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

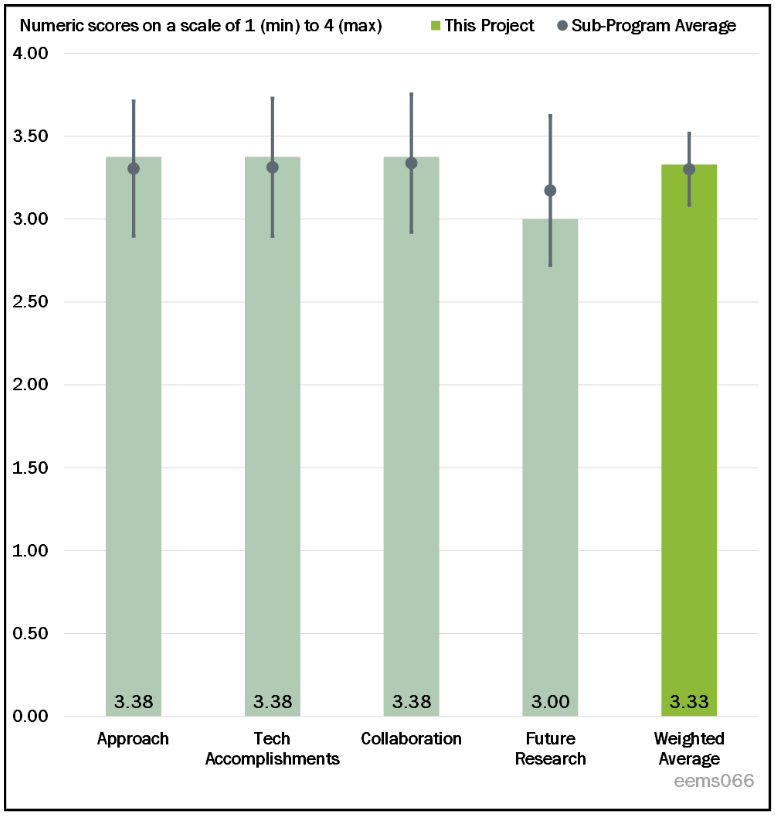

Figure 3-30 - Presentation Number: eems066 Presentation Title: Livewire Data Platform–A Solution for Energy Efficient Mobility Systems (EEMS) Data Sharing Principal Investigator: Lauren Spath Luhring (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer was really impressed with the LiveWire Data Platform (LDP), said it is very user friendly, and was thrilled to hear that the 2020 DOE VTO funding opportunity announcement (FOA) is requiring that data generated by the funded projects must be shared via the LDP. The reviewer thought this is a huge step toward overcoming the cultural barriers associated with not wanting to share data.

The reviewer thought there is a real opportunity here to cross reference data.transportation.gov (DTG) datasets on the LDP, and vice versa. DTG is likely to have different users (e.g., state DOTs, MPOs, traditional transportation consultants) from LDP (e.g., folks that traditionally work with DOE). By pointing to the datasets available on both sites, this might increase the likelihood that the user (e.g., student, researcher) finds the needed dataset(s). If the project team decides to move forward past the go/no-go point, the reviewer encouraged the team to consider a task to coordinate this.

Recently, the reviewer looked at the LiveWire website and started to make an account to see the available datasets. The reviewer was a bit intimidated by the question, “Justification – What EEMS project are you working on?”. The reviewer assumed that part of the motivation behind this question is to give dataset owners more information about the intended use of the data; however, the reviewer was afraid it might send the message that someone cannot create an account or access the data if not affiliated with an EEMS project (unless that is truly the intent, in which case it is highly effective).

Reviewer 2:
This reviewer observed a sound approach to creating the LDP platform by leveraging two existing, successful platforms and allowing data access via application programming interface (API), downloads, etc.

Reviewer 3:
The team developed automated tools to create metadata and standardization in order to make sharing data more efficient and straightforward to use.

Reviewer 4:
Overall, the project approach appears logical, well designed, and feasible. Philosophically, it approaches the challenges from two directions: the technology and the cultural (people) aspects. Specifically, the project consists of three phases: developing the new LDP and inventorying the desired datasets, including outreach to, and for, data and users; launching of the LDP and shifting emphasis to growth of datasets and users; and transitioning to LDP operation and continuing to grow data/users and track impacts/benefits pending successful go/no-go in year 2.

Good approach to leverage existing successful data platforms (a2e.energy.gov, api.data.gov, and the API Umbrella) and extensively incorporate information from the Transportation Secure Data Center (TSDC) and FleetDNA as foundational data building blocks.

The approach mentioned on Slide 7 mentions addressing historical challenges by providing "A community - builds partnership and collaboration rather than competition." It does mention that new features enable data owners to request information on how data will be used before granting access and manage visibility and access to data. It would be beneficial to provide further insights and details on how cultural (people) barriers to sharing data can be overcome.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Accomplishments include site redesign for better user experience, file upload, metadata creation tools, increased data, and user registrations. Very impressive!

Reviewer 2:
According to self-reported data on Slides 4 and 5, the project is on or somewhat ahead of schedule. The reviewer also thought that the selected performance measures for the go/no-go decision are effective.

Reviewer 3:
Site usability seems good from both sides. The reviewer could tell that a lot of work went into developing the back end. Having registered users from 18 different organizations seems broad. However, having only 9 projects hosted and 12 in the pipeline so far seems like too few. The reviewer was glad that VTO will require project data to be stored here because there is a lot of potential. There are major barriers when it comes to sharing data, not just making the data usable to others but also legal issues. The team has done a good job on a very difficult, multi-faceted problem. The team has been receptive to feedback and has improved the user experience in response.

Reviewer 4:
The project does a good job of identifying the historical data challenges right up front, including technical (platform) and cultural (people) challenges, including details therein.

The project appears on schedule as a 3-year project starting in October 2018 with a current estimated completion of 60%.

A steady stream of technical progress has been demonstrated on achieving quarterly milestones over the last year, with clearly identified task leads. Overall, most seem to refer to information technology (IT) advancements to further upgrade the functionality of the LDP, including improved usability of existing datasets; data download advancements; platform success measurement and reporting; growth in users and available data; metadata creation tools; file upload features; and site redesign for a better user experience. Another important technical accomplishment mentioned under the reviewer-only slides is that access is standardized and managed through authentication processes that ensure privacy at the level desired by researchers for their data.

Of particular interest to the reviewer is the measurement and reporting of platform success. Have metrics use, engagement, and impact been defined at this point for, say, December 2020 and project completion in September 2021? Metrics extending out to September 2020 have been provided, appear relevant, and are on track.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration and coordination with ORNL, Carnegie Mellon University, PNNL, and INL are well executed.

Reviewer 2:
It seems like the team from NREL, PNNL, and INL was able to work well together on several levels.

Reviewer 3:
The project team of the NREL, PPNL, and INL is strong and diverse, and there appears to be relatively extensive further interactions and collaborations with other entities, such as ORNL, universities, and FOA and Lab Call awardees. As mentioned in the presentation, it is important to continually work to build collaboration and coordination with others, particularly potential data sources, including those outside the immediate orbit of DOE and VTO. Ultimately, this is likely to heavily influence the overall long-term success of the project.

Reviewer 4:
It is hard to assess this question when only one team member from one National Laboratory and university is responsible for providing Laboratory updates. However, as far as the reviewer can tell (based on Slides 4 and 5), the project seems to be well coordinated across Pacific Northwest National Laboratory (PNNL), NREL, INL, and EEMS partners. The reviewer would like to see other government agencies added as partners, as suggested above.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The decision point in June 2020 is logical and has appropriate performance assessment indicators in place. As far as the reviewer knew, that is the last decision point for the project, which is not scheduled to end until September 2021. The upcoming milestones (until September 2020) are well described and seem to be logical next steps. However, the proposed research for the last year of the project- (highlighted on Slide 21) is described at too high a level of detail to be evaluated here. In the future, the reviewer suggested a more granulated list of tasks (like those listed on Slide 5) in the "Reviewer-Only" slides to aid reviewers with assessing the question.

Reviewer 2:
Proposed future work including user management, elimination of impediments to sharing data, evolution of the metadata structure, and protection of the controlled data will improve LDP.

Reviewer 3:
Overall, the proposed future research is good, but more emphasis (and detail) should be placed on addressing the human factors impeding data sharing with the LDP. Are there any high-end tools within the LDP now or planned for the future that would allow data providers to manipulate and analyze data in unique and value-added ways? This gets to the core challenge of further incentivizing entities to contribute data to the LDP. Furthermore, how do you “handle” entities that frequently access data via the LDP and have data of their own but refuse to share it? Do some protocols need to be in place so that, eventually, extensive data “users” need to also be data “providers” or access to the LDP?

Under the remaining barriers and challenges section, three items are mentioned including legal challenges around non-disclosure agreements (NDAs) and licenses; manual processes that impede sharing by rapidly evolving, complex modeling projects and datasets; and human factors. It is good to see that the project has clearly identified these specific challenges moving forward.

Reviewer 4:
The team is attempting to address both technical and human factors to facilitate broader use of the LDP, but this reviewer commented that legal issues were not mentioned.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project absolutely supports overall DOE objectives. Goal 7 of the EERE Strategic Plan is to “Enable a High-Performing, Results-Driven Culture through Effective Management Approaches and Processes.” Accessible data are paramount toward that strategic goal. This project also improves DOE’s compliance with the Open Government Data Act. By making the data available for other researchers to use, it significantly increases the return on investment of the government taxpayer funds used to fund the collection of the dataset.

Reviewer 2:
This project supports DOE EEMS’ stated objective of developing tools to address transportation energy-use reduction via optimized mobility systems.

Reviewer 3:
Yes, the LDP is very relevant to overall DOE and EEMS’s objectives, given the critical need for (but lack of tendency to share) cutting-edge data in this evolving field.

Reviewer 4:
EEMS aims to “support research and development at the vehicle, traveler, and system levels, creating new knowledge, insights, tools, and technology solutions that increase mobility energy productivity for individuals and businesses,” and this project created a data portal to ensure high-quality data are available for anyone to access and use.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The FY 2020 budget of $1.5 million is adequate to accomplish the target deliverables.

Reviewer 2:
At $3 million over 3 years, the funding identified for this project is sufficient.

Reviewer 3:
It is expensive to set up the backend of the necessary data portal, and the team has managed to accomplish a lot, given the resources. Long-term funding of the project is still needed.

Reviewer 4:
Because the reviewer did not have experience building a data repository and interface like LiveWire, the reviewer deferred to the PI (who did not mention any budgetary shortfalls) and concluded that the resources are sufficient.

Presentation Number: eems067
Presentation Title: Virtual and Physical Proving Ground for Development and Validation of Future Mobility Technologies
Principal Investigator: Dean Deter (Oak Ridge National Laboratory)

Presenter

Dean Deter, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 33% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

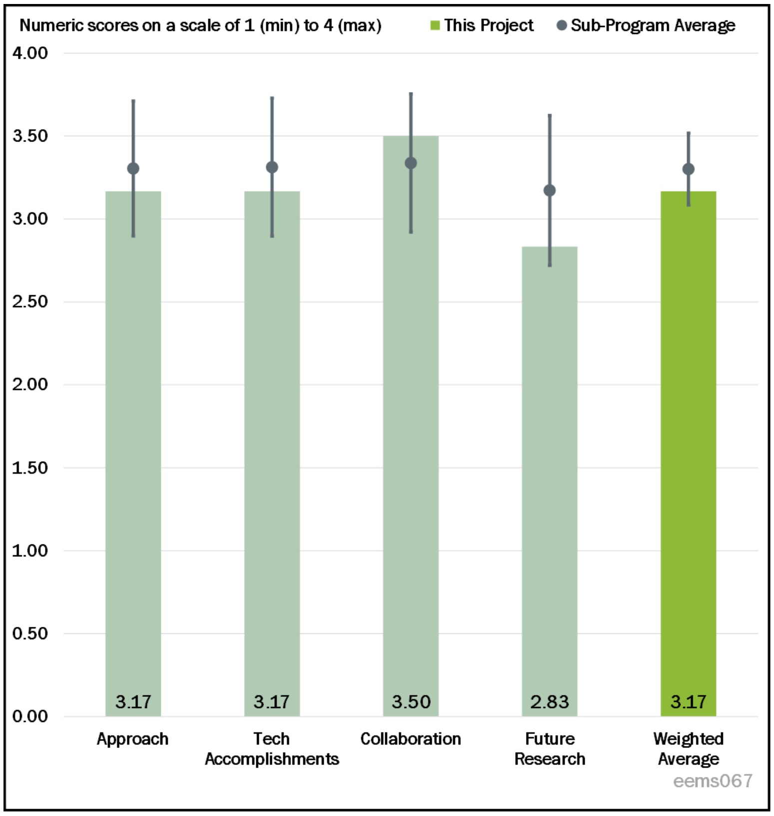

Figure 3-31 - Presentation Number: eems067 Presentation Title: Virtual and Physical Proving Ground for Development and Validation of Future Mobility Technologies Principal Investigator: Dean Deter (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Hardware-in-the-loop (HIL) (vehicle connected to dynamometers in the laboratory and driven in accordance with traffic simulations) is typically an approach that seeks to provide real-world driving realism, with the need for actual on-road driving. Yet, in later planned tasks of the project, there will be track testing. With track testing planned, it is unclear why was there a need for HIL.

Reviewer 2:

The project objective is quite broad, so breaking it down into two tasks helps bring focus to specific areas of the effort. The reviewer assumed it would be hard to tell if the final objective of integration has been reached since there are so many aspects to address. Completing the goals of the tasks helps to chip away at the overall objectives. It seems like any one aspect of this effort could be considered its own stand-alone project.

Reviewer 3:

The approach to performing the work is good but still not comprehensive enough. It seems that two approaches—HIL (dynameter plus vehicle plus dSPACE plus CARLA) and software-in-the-loop (SIL) (IPG plus VISSIM)—are examined separately. It would be more interesting to see a unified approach or platform that integrates all of these components together, or provides further discussion on the potential challenges to develop a unified approach.

It is not clear how the vehicle-to-anything (V2X) communication is modeled in the SIL environment. Is it based on the function provided by VISSIM or IPG, or using some kind of HIL strategy? Either way, the reviewer had potential concerns. Firstly, it is unclear if VISSIM or the IPG module is good enough for the network simulator compared to others such as NS3 or omnet++. Secondly, there may be some inconsistency issues for HIL testing on communication performance as compared to pure simulation or pure real-world testing.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer was impressed with the Connected and Automated Vehicle Environment lab set up.

Reviewer 2:
It is understandable that there must be quite a lot of details or barriers the research team has to overcome throughout the project.

Reviewer 3:
The project appears to be a bit behind schedule, primarily due to COVID-19.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration across the project team appears well coordinated.

Reviewer 2:
The research team is strong and the collaboration makes sense.

Reviewer 3:
Signs of collaboration were demonstrated through joint development with project EEMS082—"As part of joint development with project EEMS082 led by the American Center for Mobility (ACM), the ACM test facilities HD map has been shared and integrated into both IPG Carmaker and VISSIM to create a digital twin."

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The benefit of on-track testing is unclear when (thus far) the project has been developing a HIL environment. This same point was raised earlier about the approach.

Reviewer 2:
The reviewer thought the future work stated seems reasonable. It is not clear how the team expects to tackle the remaining challenges and barriers related to computing power and integration challenges.

Reviewer 3:
Since this work requires system integration with real-world testing (e.g., HIL), it would be more interesting to see any adaptation plan or risk-mitigation strategy due to the breakout of COVID-19.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is very timely and important in terms of creating an advanced, cost-effective, immersive CAV modeling and testing platform to support future DOE research.

Reviewer 2:
Developing technologies for CAVs and developing tools to test such technologies are important for future transportation systems.

Reviewer 3:
Understanding CAVs is key to the growth of transportation capability and developing this area with this project supports DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Allocated resources seem appropriate for ongoing and planned tasks.

Reviewer 2:
The reviewer believed the resources from all kinds are sufficient for the project to achieve the stated milestones. One potential issue is the interruption and disturbance caused by COVID-19.

Reviewer 3:
Physical testing labs and huge computing requirements consume a lot of funding. The funding seems barely enough to accomplish the stated tasks. If these are the tasks, then how DOE should prioritize the budget is another question in itself.

Presentation Number: eems069
Presentation Title: Next-Generation Intelligent Traffic Signal for Multimodal, Shared, and Automated Future
Principal Investigator: Andrew Powch (Xtelligent)

Presenter

Andrew Powch, Xtelligent

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

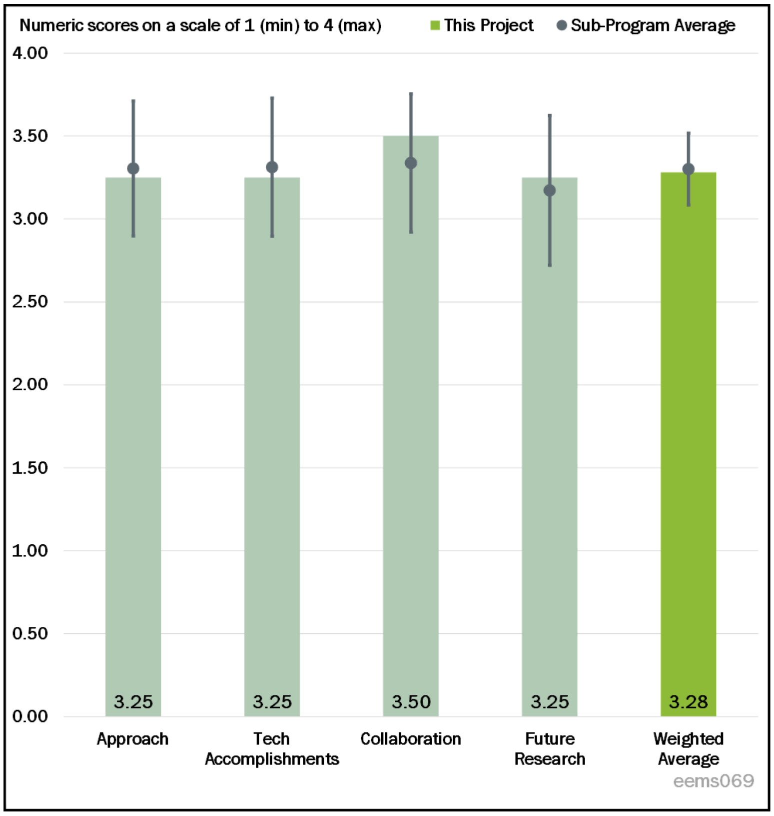

Figure 3-32 - Presentation Number: eems069 Presentation Title: Next-Generation Intelligent Traffic Signal for Multimodal, Shared, and Automated Future Principal Investigator: Andrew Powch (Xtelligent)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach is well thought out and a practical way to demonstrate the technology.

Reviewer 2:

The overall approach is good. One significant item that is not included in the current approach is the use of a robust traffic simulation model. A traffic simulation model that accurately represents the Proportionally Fair (PF) Adaptive Traffic Control System (ATCS) algorithm and the data types and latencies of data provided from the potential data partners could be used to investigate the impact of various market penetration levels and data sources (either single data sources or data sources in combination). This could also be used to identify targeted performance levels for the system. This type of evaluation capability would provide for a much more robust project and could eventually be used by those local agencies who may consider implementing such a system.

Some clarifications in a few of the project details would be helpful, such as a clearer and more complete definition of green-time utilization and slack time. It is clear that these are inverse terms, but a detailed definition of green-time utilization and its calculation would be helpful. A clearer and more complete description of the proposed corridor that is being instrumented for testing would also be helpful.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Results indicate the concept works and produces the anticipated benefit to traffic throughput.

Reviewer 2:
There has been good progress on the project so far, but as described, the reviewer said that there could be some significant delays due to the COVID-19 induced traffic reductions. The implementation of a central computing approach (as opposed to local intersection computing) is a positive accomplishment and should make this project easier to implement.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Partnerships span a number of private and public entities, which is not easy to achieve.

Reviewer 2:
Coordination among existing team members seems good. As stated in the risk section, it may be a little difficult to maintain the focus of the local transportation agencies if they have to deal with COVID-19 induced traffic issues that would have a higher priority than this project. To the extent that the “data partners” are part of the project team, the sooner these partners can be identified, the better continuing progress into Phases I and II will be.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Next steps were appropriate to the reviewer and could improve the adoption prospects of the technology.

Reviewer 2:
The overall planning for future work is good. However, there are some risks that are beyond the control of the project team, specifically restoration of traffic volumes to “normal” levels and commitments of data partners. Of these risks, the lack of commitment of data partners is probably the higher. If sufficient data partners are not participating, the project will not have sufficient market penetration so that the traffic volumes will not be representative of traffic on the network. This would make the traffic-signal timing non-responsive to the traffic in the scenario where no infrastructure-based data collection is used (i.e., objectives 4 and 5 of traffic control with connected vehicle data only).

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Smart traffic-control technology is an enabler for the DOE VTO objective of transportation system energy consumption reduction.

Reviewer 2:
Yes, the project supports the overall DOE objectives by implementing a traffic-signal control system that is designed to reduce delays, and hence, unnecessary use of fuel along traffic-signalized corridors. However, it is not apparent from the provided documentation how the fuel benefits will be calculated.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project is progressing well with the given funding.

Reviewer 2:
Yes, the resources seem sufficient.

Presentation Number: eems072
Presentation Title: Charging Infrastructure Needs for Electrification of Freight Delivery Vehicles
Principal Investigator: Victor Walker (Idaho National Laboratory)

Presenter

Victor Walker, Idaho National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

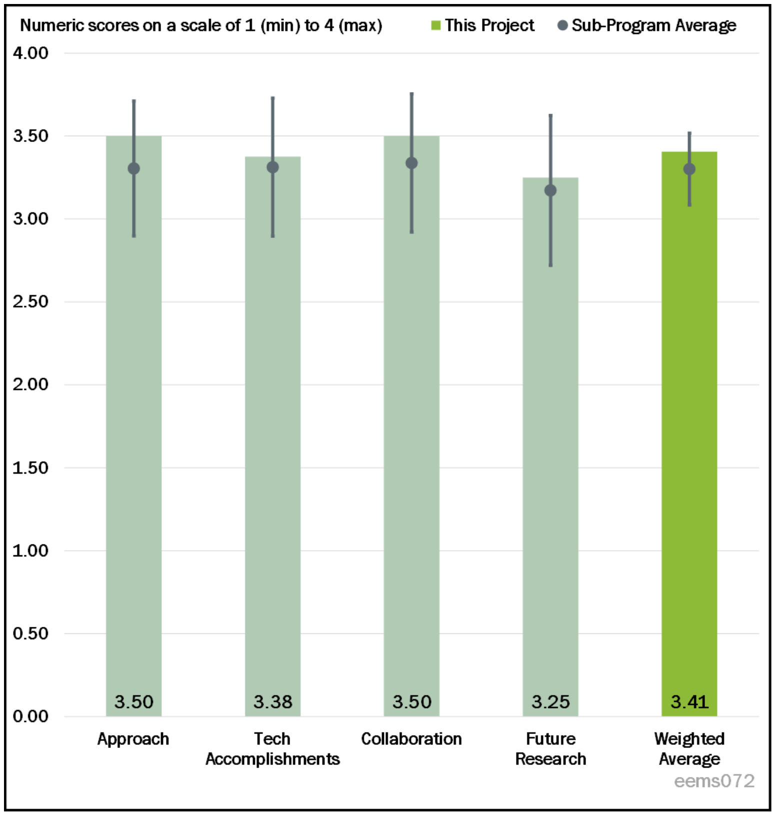

Figure 3-33 - Presentation Number: eems072 Presentation Title: Charging Infrastructure Needs for Electrification of Freight Delivery Vehicles Principal Investigator: Victor Walker (Idaho National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach was well thought out and executed. The project team defined freight use cases and performed market and stakeholder analyses for at least three cases. The team created infrastructure scenario descriptions for at least two use cases based on real-world data and created a model to simulate change points. The team produced a report on charging infrastructure strategies to support Class 7 and 8 trucks and FMLM delivery vehicle electrification.

Reviewer 2:

This project approach allowed for an evaluation of electrification requirements for various freight truck fleet applications. The approach followed a progressive research pathway of segmenting and analyzing the truck freight sector, selecting high-value segments for analysis, collecting real-world fleet data to understand duty cycles and operations, and then assessing opportunities for electrification during daily operations. The reviewer indicated that the approach resulted in meaningful insights in answering questions about effective electrification for the trucking industry.

Reviewer 3:

The main approach the team took was to find three different representative freight case studies to focus their efforts on. These were informed by real-world data from freight trucks (loggers). The reviewer appreciated that a variety of charging options were examined because of their impact on meeting the fleet needs as well as the costs.

Reviewer 4:
This reviewer noted a collaborative approach among three National Laboratories leveraging their core competencies—INL for EV charging, NREL for fleet duty-cycle understanding, and ORNL for freight vehicle characterization. The reviewer also observed a systematic approach starting with truck industry segmentation, select application data-logging of trucks, and charging scenario investigations.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project team characterized the on-road freight movement industry, collected real-world driving-cycle data on three fleets, and developed charging scenarios for three different freight vehicle applications. According to the reviewer, these are good accomplishments for a three-Laboratory collaboration in a year's time frame.

Reviewer 2:
The researchers completed the three prescribed milestones within the 1-year timeframe including market segmentation analysis and identification of case study fleets; characterization and simulation of charging infrastructure scenarios based on real-world duty-cycle analysis; and assessment of practical charging scenarios for supporting regional and long-haul truck operations. The research resulted in some valuable insights on electrification applications for various types of freight truck fleets, such as ubiquitous charging installations across fleet operations is not necessarily the best solution; fleets can take advantage of natural opportunities for charging in daily operational cycles; low- and-medium-power (and thus lower cost) charging at delivery and depot locations can satisfy many fleet requirements; and high-speed charging at truck stops can meet typical long-haul fleet requirements.

Reviewer 3:
Based on fleet-collected data in two cities, the project team developed route data to produce typical charging needs. On-route opportunity charging was also researched.

Reviewer 4:
The objectives of the study were met, but the reviewer did not see where the results were published or shared with interested folks and fleets. The slides do not show any publications or links to mentioned reports mentioned (and a quick internet search came up empty handed). A future tool based on these results would be powerful. Fleets could use this tool to examine what makes sense for them based on their specific fleet characteristics and needs.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration among three National Laboratories leveraged their core competencies. Involvement of on-road freight industry stakeholders (fleets and consortia) contributed to the project's success. Inclusion of current electric fleet experiences would be helpful to confirm hypothetical charging scenarios and particular challenges or concerns associated with each one.

Reviewer 2:
The project employed good collaboration with both the NREL and ORNL. The researcher identified the roles of each team member. In response to comments from last year, the researcher added significant collaboration with industry, including trucking and parcel delivery fleets, and direct discussions with the American Trucking Institute and national trucking consortia.

Reviewer 3:
The team consisted of three national Laboratories. Collaborators also participated.

Reviewer 4:
All parties performed tasks to standard, as planned.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer stated that building tools for small fleets would be very beneficial, as small fleets normally do not have the engineering assets to do so themselves. Working with industry should include several large fleets and would be a suggested course of action. Large fleets normally have engineering assets and more reliable data than smaller fleets.

Reviewer 2:
This 1-year project has been completed, but the researcher offered several suggestions for future research, including development of new tools, additional analysis of slow charging solutions for fleets, and optimizing smart grid approaches and costs. The reviewer agreed that tool development for allowing different types of trucking fleets to evaluate electrification opportunities and costs would be a valuable asset for future decision making.

Reviewer 3:
The project has been completed, and several general future recommendations have been listed.

Reviewer 4:
The project ended.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
An accurate assessment of charging infrastructure needs is imperative for electrifying fleets in a cost-effective, responsible manner.

Reviewer 2:
The electrification of the on-road freight industry has the potential of significantly reducing petroleum use.

Reviewer 3:
This project is relevant for DOE’s program in that it focuses on how to improve the energy efficiency of goods movement through electrification of freight truck fleets. Freight trucks are a critical element of U.S. freight movement, thus future opportunities for increasing their fuel efficiency through electrification is important to understand.

Reviewer 4:
Yes, understanding the barriers and opportunities of electrifying freight supports DOE’s objectives for increased mobility with less energy.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project team had sufficient recourses and proper tools to complete this project.

Reviewer 2:
The reviewer stated that $350,000 for a 1-year project among three National Laboratories seems appropriate for the scope of work. completed.

Reviewer 3:
The funding for this project seems sufficient for a 1-year project involving three national Laboratories and the technical progress achieved.

Reviewer 4:
The scope and budget seem to be a good match.

Presentation Number: eems074
Presentation Title: Smart Cities Topology–Curbs and Parking
Principal Investigator: Stanley Young (National Renewable Energy Laboratory)

Presenter

Stanley Young, National Renewable Energy Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

50% of reviewers indicated that the project was relevant to current DOE objectives, 50% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 50% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

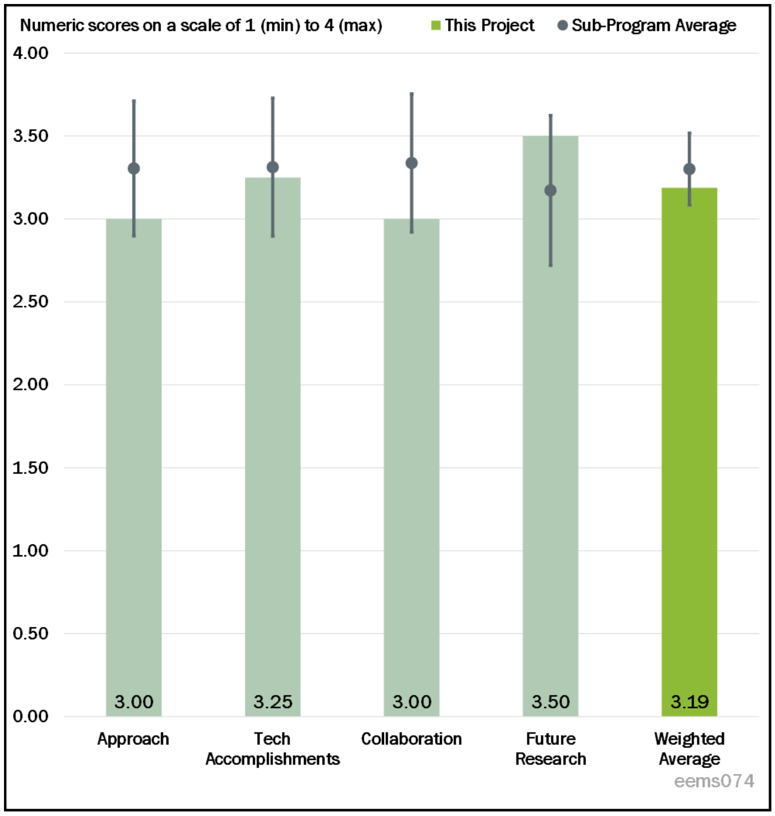

Figure 3-34 - Presentation Number: eems074 Presentation Title: Smart Cities Topology–Curbs and Parking Principal Investigator: Stanley Young (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, this project presents a good start to a new area of modeling. However, for the funding allocated, it is a very small start and more results should be visible from the investment.

Reviewer 2:

Overall, the project approach seems reasonable for achieving project objectives. The initial literature review and interviews of key stakeholder and operators of curbside activities are good first steps to capturing the latest research efforts and obtaining necessary data and information. However, the reviewer found that the presenter provided only limited details on these activities and the data and information objectives, especially as related to informing the later modeling efforts of the project. The early optimization framework effort formed the basis for the later micro-simulation work. Given the data challenges intimated by the presenter, the approach might have considered an additional focus on data capture and survey efforts, although these activities are hinted at in future research plans.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The presenter appears to have made steady progress in the project, having completed the literature review, stakeholder and expert interviews, and initial optimization framework development. The remaining micro-simulation development work looks achievable, given the current schedule.

Reviewer 2:
Progress against the project design's goals has been made; however, how the model is actually used for decision making is unclear.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
It is clear that the PIs spent sufficient time and effort engaging with real-world stakeholders on the shared curb space topic. The reviewer remarked that more collaboration with other components of the SMART Mobility Consortium and other National Laboratories operating within the Consortium is needed.

Reviewer 2:
The project team includes cross-disciplinary members including NREL, academia, industry, and government organizations. Engagement with industry and government stakeholders appears to be excellent for gathering current curbside research and valuable data and information on curbside operations, configurations, and dynamics. However, discussion of the NREL collaboration with academic team members was limited in the presentation, and their research and/or computational contributions to current project efforts were not extensively explained.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed research is reasonable, given the identified barriers.

Reviewer 2:
The current project approach provided a good foundation for curbside modeling expansion and evaluation of real-world influences. Future research plans included proposals for expanding model attributes, such as additional curbside uses (e.g., e-commerce, micro-mobility); additional, other high-valued outcomes (e.g., safety); additional stakeholder partnerships for data collection and management; and curbside pricing strategies and policy sensitivities.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer asserted that curbside activities are often overlooked in terms of traffic simulation and the associated micro- and macro-evaluation of energy and environmental impacts. Curbside activities are becoming even more relevant to this research, given the advent of TNC, e-commerce deliveries, and other novel curbside uses beyond parking and traditional bus ingress and egress. The project addresses the need for more effective modeling and incorporation of a growing mix of curbside activities into regionally broader and increasingly complex traffic simulation efforts.

Reviewer 2:
The energy component of this project is essentially non-existent. Clear identification of a pathway for why this project is necessary to inform energy technology investment or energy decision making is needed.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The FY 2019 and FY 2020 funding appear to be sufficient for the prescribed efforts.

Reviewer 2:

While some of the project budget should be devoted to publications and presentations, it appears that this project's time and financial resource budget was excessively spent on such promotion as compared to investing time in model development.

Presentation Number: eems078
Presentation Title: Simulation Model Results for Energy and Mobility Impact of Behavioral Scenarios in POLARIS
Principal Investigator: Joshua Auld (Argonne National Laboratory)

Presenter

Joshua Auld, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 25% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

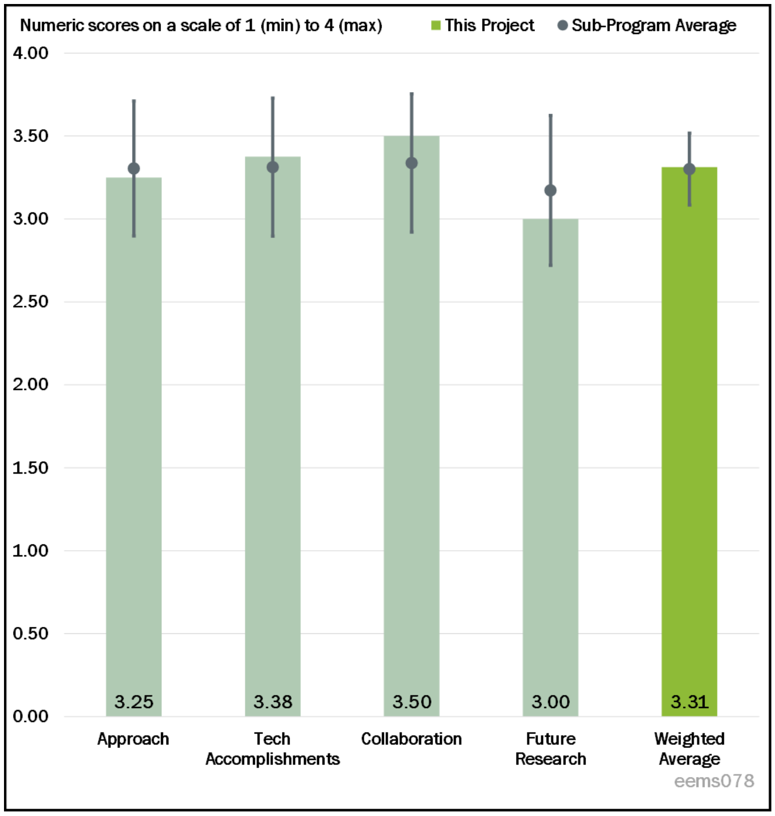

Figure 3-35 - Presentation Number: eems078 Presentation Title: Simulation Model Results for Energy and Mobility Impact of Behavioral Scenarios in POLARIS Principal Investigator: Joshua Auld (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
This year’s approach has successively built upon previous years’ accomplishments. Using the now-enhanced version of the POLARIS framework, the research evaluated 13 future vehicle technology scenarios and their impacts on energy use and MEP. This year’s work included an assessment of TNC and ride-sharing behavior, and time use and value changes due to CAV implementation.

Reviewer 2:
The approach is good, but the reviewer was not convinced that MEP is the best metric to quantify the effects.

Reviewer 3:
The approach to performing the work (i.e., enhancing POLARIS capability) makes sense to the reviewer. One major concern is about the computational efficiency of using the commercial optimization solvers (e.g., CPLEX, GUROBI). Based on the reviewer’s experience, these commercial optimization solvers may not be so reliable to provide the optimal solution of a large-scale problem in a timely manner. For specific application on a large scale, there are usually tradeoffs between optimality and real-time performance. The research team may need to develop some heuristic algorithm(s) to improve the computational efficiency at the expense of certain optimality gaps.

Reviewer 4:
The reviewer thought that the workflow ANL developed is outstanding, though the reviewer would have liked to see more transparency about the modeling subcomponents in the AMR presentations. The reviewer

struggled to understand the contribution of this presentation that should be evaluated herein versus the contributions from other presentations (e.g., Monique’s, Aymeric’s). Acknowledging that this work is very interconnected, the reviewer suggested explicitly stating the contributions of this presentation. The title of the presentation explicitly mentions model results, so that is where the reviewer focused comments.

It is hard to critically evaluate the model results without fully understanding the assumptions that were made with the models; there were not enough details about the approach to properly evaluate this. The reviewer understood that it is challenging with the ANL workflow because of the breadth of the model components used to obtain the results. In the future, this could be contained within the “Reviewer-Only” slides. Along those same lines, the reviewer knew and echoed comments that were made last year about the importance of validation and sensitivity analysis. Both of those activities are so important in order to build confidence in the modeling results. The reviewer was also very excited to see the results in the cities that both BEAM and POLARIS are modeling. If both frameworks are able to produce consistent results, it will significantly increase confidence in the results.

Regarding Slides 13 and 14, is the base case defined?

Regarding Slides 12 and 13, Slide 12 says that 4% of vehicle-miles traveled (VMT) are unloaded under the SAV case (which the reviewer assumed means deadheading/empty vehicles), while15% of VMT are unloaded in the Private AV case. However, on Slide 14, the SAV case has 14% deadhead VMT while the Private AV has 12% deadhead VMT. Those results seem to conflict with one another, unless the reviewer misunderstood something. The reviewer assumed the Private AV scenario would have a significantly higher deadhead VMT (current forecasts are anticipating a future in which Private AV users would send cars home once users are dropped off at work, rather than paying for expensive downtown parking, without appropriate policies discouraging this behavior). This does not seem to be represented in the modeling results.

The reviewer thought the observation of the possibly complementary effects of transit and TNCs is extremely interesting and encouraging. However, it may take some policy changes to see this come to fruition. Speaking from experience, the reviewer found that TNC drivers tend to center themselves in more urban areas and airports (more people, more likely to be assigned to someone), instead of waiting to be connected with a rider in suburbia. It tends to take longer and be less likely that a passenger will be connected with a driver in the suburbs unless a trip has been prearranged.

Regarding Slide 4: the description suggests that the microscopic traffic-flow simulator is outside of the POLARIS model. However, on Slide 8, the traffic-flow model seems to be included within POLARIS. The reviewer tried to find the Liu et al. (2018) in the bibliography, but it was not listed. The reviewer assumed it is more of a mesoscopic traffic-flow model, perhaps like Dynamic Traffic Assignment (DTA), but the documentation provided is unclear.

If POLARIS and the traffic micro-simulations are not linked, the reviewer suggested looking into how to ensure convergence between the two traffic-flow models (i.e., multi-resolution models). It needs to be a bidirectional exchange of data and results, not just taking the results from one model as inputs in the second and concluding that the results are consistent.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The researcher indicated that the 3-year project was completed in FY 2019. Several key milestones were achieved in FY 2019, including the incorporation of new activity models addressing changes in time use and value; analysis of the interaction of SAVs and traditional transit modes; quantification of system energy and MEP impacts due to time use and value changes; and new modes and technology options. The researcher shared some nice insights of varying levels of vehicle sharing and technology, vehicle automation, and ownership on the interrelationships of transportation system energy use, VMT, congestion, and MEP. Overall, this 3-year project has supported the POLARIS model as an effective transportation system evaluation tool and provided significant understanding of the energy impacts of traveler behavior and future mobility technologies.

Reviewer 2:
The technical accomplishments and progress seemed reasonable to the reviewer.

Reviewer 3:
The progress is satisfactory, but the reviewer expected more journal publications, given the scale and duration of the project.

Reviewer 4:
The project was completed on time and on budget. However, the presenter did not mention the performance indicators for the workflow development and results. It would be interesting to know how the team internally assessed performance, though the reviewer assumed the team has met all of its goals, given that the project is complete. Overall, the enhanced POLARIS capabilities are well described, but the team did not clearly articulate the 13 future scenarios that were modeled.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project exhibits diverse collaboration and coordination across National Laboratories, universities, and federal and local government organizations. The roles of team members are well described and defined. The research makes great use of universities and collaboration across multiple EEMS research projects.

Reviewer 2:
The collaboration and coordination across the project team were clear to the reviewer.

Reviewer 3:
There appears to be ample collaboration, but the collaboration efforts on EV charging does not quite show.

Reviewer 4:
It is hard to evaluate team collaboration when only one person is presenting for the entire team. However, the project was completed on time without major issues, so the reviewer presumed that collaboration worked well. The reviewer also loved Slide 8, where the presenter showed how different papers (and AMR sessions and posters) contributed to getting the results presented in this presentation. It is a very effective visual.

However, the reviewer would like to have seen end-users of the workflow (e.g., MPOs from Chicago, Austin, Detroit) as part of the project team. End-users would be able to better articulate the challenges of deploying some of the modeling contributions of the ANL workflow into the real world.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Although this 3-year project has been completed, the researcher suggested future work involving expanding and validating additional system scenarios. It is assumed that future efforts will focus on addressing the many remaining barriers and challenges identified in the presentation.

Reviewer 2:
The proposed future research made sense to the reviewer. It is great to see that not only charging facility, but also electricity grid simulation, models are part of the integration plan; that would be more of a system of systems approach. The reviewer indicated that the project has also ended.

Reviewer 3:
The project ended in 2019.

Reviewer 4:
The project ended, and the proposed future research appears extremely complex. It is going to be difficult to execute well.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Yes, this project contributes to DOE's objectives. In order to assess complex future scenarios, the workflow is absolutely necessary and is in alignment with Goal 1: Tools, Techniques, & Capabilities to Understand & Improve Mobility Energy Productivity.

Reviewer 2:
The research is very relevant to DOE's EEMS program in the areas of SMART Mobility, HPC, and simulation by supporting and expanding the POLARIS modeling platform for assessing the impacts of traveler decision behavior and future mobility options on transportation system energy and performance. This work is providing key insights on traveler decisions and technology integration within the developing framework of POLARIS.

Reviewer 3:
This project will definitely support the overall DOE objectives by further improving the existing modeling tool, POLARIS, and capability. The project is considered to be a continuing effort in energy efficient mobility system simulation (agent-based modeling).

Reviewer 4:
The project supports DOE objectives in understanding what types of technologies are most promising for energy efficiency.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources are considered to be sufficient in terms of the time (3 years), funding (approximately $1.4 million), and team members (various stakeholders) to achieve the stated milestones.

Reviewer 2:
The funding level appears to be sufficient for the efforts prescribed and multiple organizations involved.

Reviewer 3:
Project resources are sufficient.

Reviewer 4:
The project ended in 2019.

Presentation Number: eems079
Presentation Title: Travel-Time Use and Value With Mobility Services
Principal Investigator: Paul Leiby (Oak Ridge National Laboratory)

Presenter

Paul Leiby, Oak Ridge National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

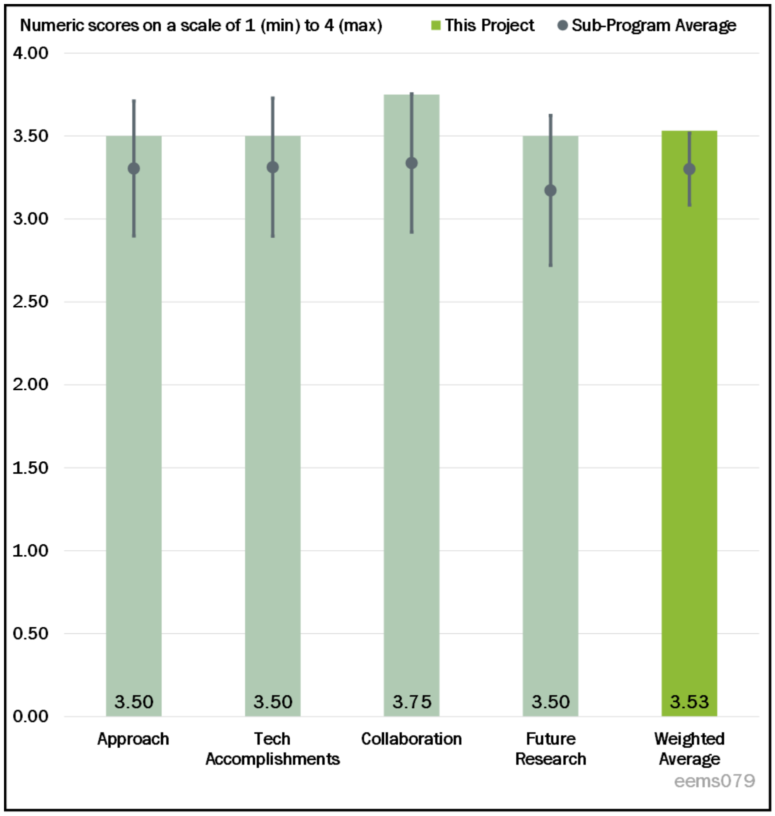

Figure 3-36 - Presentation Number: eems079 Presentation Title: Travel-Time Use and Value With Mobility Services Principal Investigator: Paul Leiby (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The focus of this study is to develop quantitative estimates of how the value of travel time (VOTT) may change when time spent driving is replaced by time spent riding in a car. Specifically, the project sought to determine insights from VOTT for car sharing and ride hailing modes (basically a proxy), and subsequently to make inferences with regard to AVs. Other studies have been conducted, but they had notable weaknesses, including "stated preference/choice" methods based on survey responses, and the use of inappropriate proxies (such as trains or transit), which are dissimilar to AVs. The approach uses real-world data from app users on trip alternatives and their choices. The approach employs two discrete assessment methodologies, including Multinomial Logit and Mixed Logit discrete modeling pathways.

The presentation does a good job of identifying and addressing barriers including the following: determining the value and productivity from new mobility technologies; difficulty in sourcing empirical real-world data applicable to new mobility technologies; and the complex role of the human decision-making process in mobility systems.

Reviewer 2:

This research uses unique datasets to provide insight into a very difficult question.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project has achieved a number of accomplishments, including the development of suitable discrete choice models (Multinomial Logit and Mixed Logit with Error Components). Results from both estimation models are similar, indicating a significant reduction in cost ($16-$23 per hour) by using ridesharing—a proxy for AVs—versus driving a car. This shows the greater utility and lower cost of travel time of ridesharing, and thus AVs. These VOTT results are higher than previous studies, which used different parameters. For example, this study utilizes unique data, which in general applies to frequent urban users having higher than normal incomes.

The high-level technical accomplishment is that it has been shown that using real-world trip choice data suggest that a large time cost savings can be achieved from riding as opposed to driving.

The reviewer indicated that there are notable caveats to this study, which were mentioned in the presentation. These include the limited size of the dataset, a lack of clarity if car share driving is more or less convenient than a conventional private car, and that VOTT is known to vary significantly with trip purpose, urgency, and driver income.

Reviewer 2:
The research provided defensible answers.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
For a small task, the project has excellent collaboration and coordination. This includes collaboration with the University of Washington (empirical analysis), Migo (the mobility-as-a-service aggregator, which is providing the data, pre-processing, and interpretation), and ANL.

Reviewer 2:
It appeared to the reviewer that the prime and subcontractor worked seamlessly.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
In short, for future research this project proposes to strengthen and extend the existing estimates to a wider range of travelers and trip types. It would allow another dimension of variations and further refine estimates of VOTT for alternative car-based modes. This proposed future work would further refine and improve the accuracy of the study by expanding the dataset, seeking to improve controls and proxies for rider characteristics (like income) and obtain and utilize better data differentiating travel time for trip alternatives.

This proposed future research makes good sense, especially given the importance of understanding VOTT and the successful outcomes demonstrated by this project. As a prelude to any future efforts though, a cursory cost-benefit analysis may be beneficial to further validate the need for additional study. Eventually, a point of diminishing returns will be reached.

Reviewer 2:
The project has ended.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Yes, this task is very relevant. Understanding VOTT is critical for assessing behavior and the benefits of new mobility technologies. Understanding the monetary VOTT is a major determinant of travel behavior and is the principal component of cost-benefit analyses of transportation infrastructure investments. While there has been a long history of similar analyses, the reviewer commented that the impact of automation has not been extensively researched and is highly uncertain. This is exacerbated by the lack of real-world data on VOTT in automated vehicles.

Reviewer 2:
The project helps decision makers understand VOTT as they look to promote ridesharing strategies.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project has successfully been completed and met its objectives with a very modest budget of $75,000, which is commendable.

Reviewer 2:
The resources are sufficient.

Presentation Number: eems081
Presentation Title: Nationwide Energy and Mobility Impacts of CAV Technologies
Principal Investigator: David Gohlke (Argonne National Laboratory)

Presenter

David Gohlke, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

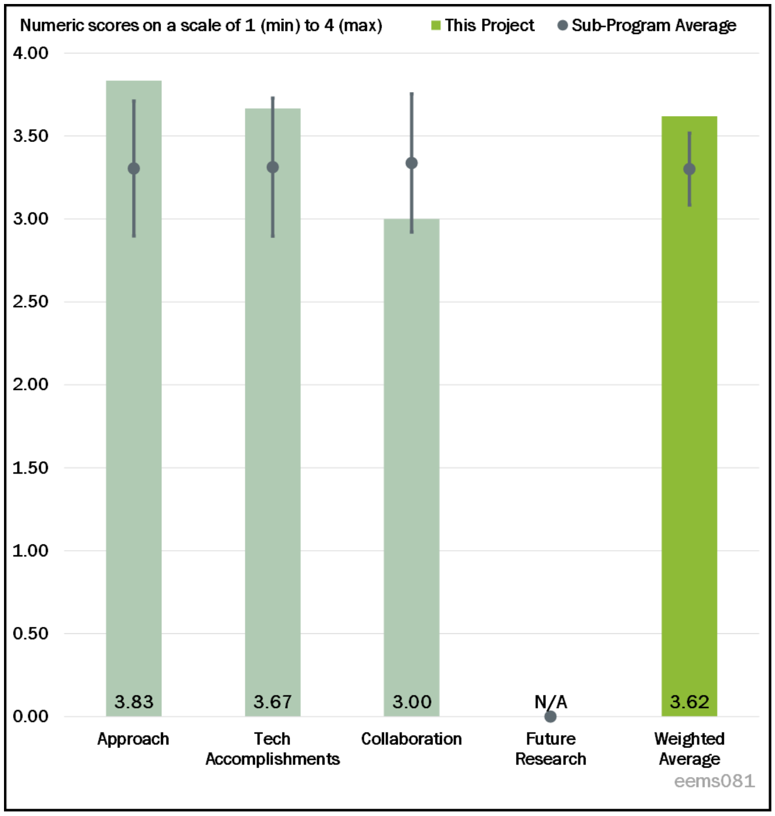

Figure 3-37 - Presentation Number: eems081 Presentation Title: Nationwide Energy and Mobility Impacts of CAV Technologies Principal Investigator: David Gohlke (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The Monte Carlo approach is by far the most plausible way to estimate the range of impacts in future scenarios. According to the reviewer, it is less prone to constraints of assumptions compared to a mechanistic simulation approach.

Reviewer 2:

This project had a very comprehensive approach to literature review for identifying the existing studies relevant to energy use and mobility impacts of CAVs. It was well designed to calculate distributions of impacts due to CAV technologies on VMT and total energy consumption for LD vehicles.

Reviewer 3:

The reviewer found the approach to be very clearly laid out across multiple slides. The project team examined the impacts of CAVs on VMT, fuel economy, and net energy consumption for LD vehicles, and repeated the analysis under various use-case scenarios. The work incorporated a wide range of existing literature (reviewing, for example, over 500 related documents), and variables and factors that accounted for road type (city versus highway), congestion level, etc. The presentation was also delivered in a very accessible, audience-friendly way (with clear graphics and explanations).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project has ended and was 100% completed. Accomplishments and key finding, (such as top factors leading to an increase in energy and fuel consumption, VMT, etc.) are clearly outlined in the presentation, including associated graphics. The work appears to have been successfully finished on schedule.

Reviewer 2:
The project was completed in December 2019 and met all of the milestones, concluding with a comprehensive final report. The team identified 24 different factors that contribute to VMT and energy consumption of CAVs in a review of 500 different reports.

Reviewer 3:
The project was successfully completed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration efforts were generally clearly laid out in the presentation, with ANL providing lead analysis, writing, and the literature review; NREL providing a literature review and analysis methodology; and ORNL providing analysis methodology and literature review.

Reviewer 2:
ANL collaborated with ORNL and NREL in this project.

Reviewer 3:
Project collaboration appears to have been adequate.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The project has ended and no specific future research has been proposed. The reviewer suggested that it would likely be beneficial to repeat this project in a couple of years to update the findings and help identify future CAV research needs.

Reviewer 2:
The project has been completed, ending December 31, 2019.

Reviewer 3:
The project ended.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
As is stated in the presentation, this analysis explores CAV efficiency and demand, identifying potential levers for future R&D to reduce nationwide fuel consumption and improve energy security. As cited in the presentation, "the EEMS subprogram supports early-stage research to support industry innovation that improves the affordability and energy productivity of the overall transportation system." This research is supporting DOE objectives to improve energy efficiency.

Reviewer 2:
This project supports the overall DOE objectives by providing supporting justification for future VTO research in CAVs, which would lead to reductions in petroleum consumption.

Reviewer 3:
The reviewer commented that the results shown on Slide 11 provide a clear reference point for decision makers on which technologies to focus on first.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This was a 15-month project funded by a total of $280,000 among three National Laboratories. As a follow-on to the initial literature review a few years ago, the reviewer stated that the funding was appropriate for the scope of work.

Reviewer 2:
Project resources are sufficient.

Reviewer 3:
Funding for this project appears to have been sufficient.

Presentation Number: eems082
Presentation Title: Validation of Connected and Automated Mobility System Modeling and Simulation
Principal Investigator: Jeffrey Rupp (American Center for Mobility)

Presenter

Jeffrey Rupp, American Center for Mobility

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

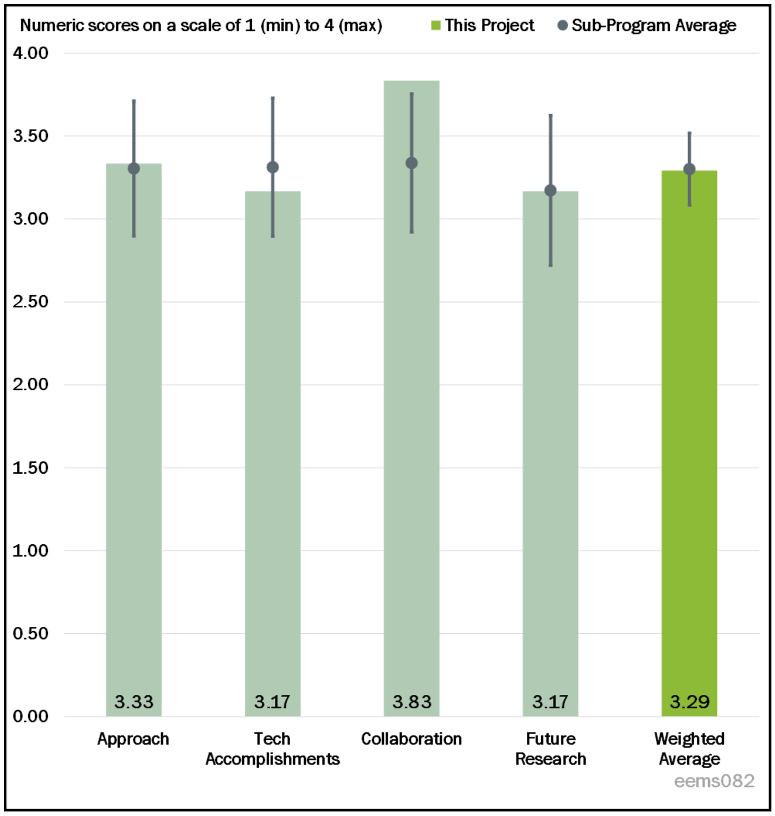

Figure 3-38 - Presentation Number: eems082 Presentation Title: Validation of Connected and Automated Mobility System Modeling and Simulation Principal Investigator: Jeffrey Rupp (American Center for Mobility)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Very pragmatic plan and activity that is progressing well.

Reviewer 2:

The project aims to develop a realistic but controlled environment for on-road testing of CAVs.

Reviewer 3:

The reviewer had no concerns about planned future work. The tasks proposed on Slide 24 all seem reasonable, logical, and contribute toward the overall goal of being able to test realistic CAV scenarios.

The reviewer was concerned the project team underestimates the task of making sure human drivers are appropriately represented in the simulations, especially if mixed traffic simulations are planned. The team is planning to use the VISSIM micro-simulation software that has built-in, car-following, and lane-changing models. However, the reviewer encouraged the team not to rely on the default parameters to accurately model driving behavior. Many studies have shown that, although these models are able to capture driving behavior at a high level (e.g., appropriate capacity, corridor speed, corridor travel time estimates), the models produce trajectories that are not consistent with what is observed in real traffic data. Before running any sort of evaluation to validate transportation system performance, the reviewer encouraged the team to calibrate the human driver models in the analysis using trajectory-level data. The Strategic Highway Research Program 2 Naturalistic Driving Study datasets, the FHWA reconstructed Next Generation Simulation dataset, or the FHWA drone data collection project are all potential data sources to avoid additional data collection efforts.

Additionally, one of the things this reviewer recently thought about is how model projects are validated. Simulations estimate that there could be 4,000 or more vehicles per hour per lane if all vehicles are in CACC mode, but how realistic is that? Model accuracy is improving by making the model components more accurate (e.g., vehicle dynamics models, car-following models), but will that translate to more accurate estimates of performance? The reviewer was unsure if anyone knows that for certain. The reviewer thought VIL and augmented reality (AR) systems like this may be a way to get "ground truth" performance data before reaching high market penetration rates on the roadway. The reviewer encouraged the team to think about how to incorporate this into future research.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
There are several barriers, which are unknown at this moment. They are defined well, but there are likely to be more.

Reviewer 2:
The project is still in its very early stages. It appears slightly behind the planned progress, but it is fairly understandable considering COVID-19.

Reviewer 3:
This project is 8 months into its first year of activity. Thus far, progress seems reasonable (especially considering issues related to COVID-19). However, there are no performance indicators listed in the presentation on which to base the evaluation; the reviewer suggested adding them for next year's AMR.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There is a clear chart of responsibilities and regular meeting cadence.

Reviewer 2:
Collaboration appears to be well coordinated.

Reviewer 3:
It is hard to assess this question when only one team member is reporting the progress of the team. However, the fact that NDAs have been negotiated and put in place suggests that collaboration is alive and well within the team. The Zoom background was also a really nice touch on Slide 21 and made for a very effective visual!

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Further ideas were listed, including cybersecurity.

Reviewer 2:
The planned tasks for 2021 could be made more concise. Testing weather effects via simulation is understandable, but "artificial" weather effects?

Reviewer 3:
This team described future work in extensive detail. It is both thorough and logical, and the reviewer had no major criticism. If the goal is to evaluate scenarios with mixed traffic (e.g., simulated human vehicles), then the project team should not underestimate the importance of properly calibrating the VISSIM (Wiedemann) model for human driver behavior. The default parameters were calibrated based on driving behavior on the

German Autobahn and are not representative of real-world driving in American cities and freeways. The reviewer will not elaborate on that here because it was in the approach section.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer thought that this project is so important toward validating the work that had been completed under SMART 1.0, but also thought it is important to start validating transportation system-level benefits (e.g., can 4,000 vehicles per hour per lane capacities using CACC really be achieved?). Right now, no one is close to having that type of ground truth data. However, HIL, VIL, and AR systems (like the one the project team is starting to build) are a huge step toward acquiring that type of data. The reviewer was so excited to see the progress that will be made between now and AMR 2021.

Strategic goal #1 for EEMS is to develop new tools, techniques, and core capabilities to understand and identify the most important levers to improve the energy productivity of future integrated mobility systems. Not only is this project developing a new capability, but it is also going to provide a way to ensure that the new tools and capabilities developed by other EEMS projects are accurate.

Reviewer 2:
Automated vehicles (and developing the means to test and improve them) are important for future transportation systems.

Reviewer 3:
This reviewer emphasized that, eventually, the information will be correlated to energy use.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project encompasses excellent academic and laboratory partners, but should have an industry partner.

Reviewer 2:
The allocated resources seem reasonable for the planned tasks.

Reviewer 3:
The reviewer lacked sufficient experience in this area to make a meaningful comment. However, the PI did not mention any concerns with funding; so, the reviewer assumed that means the funding is reasonable.

Presentation Number: eems083
Presentation Title: CIRCLES: Congestion Impact Reduction via CAV-in-the-loop Lagrangian Energy Smoothing
Principal Investigator: Alexandre Bayen (University of California at Berkeley)

Presenter

Alexandre Bayen, University of California at Berkeley

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

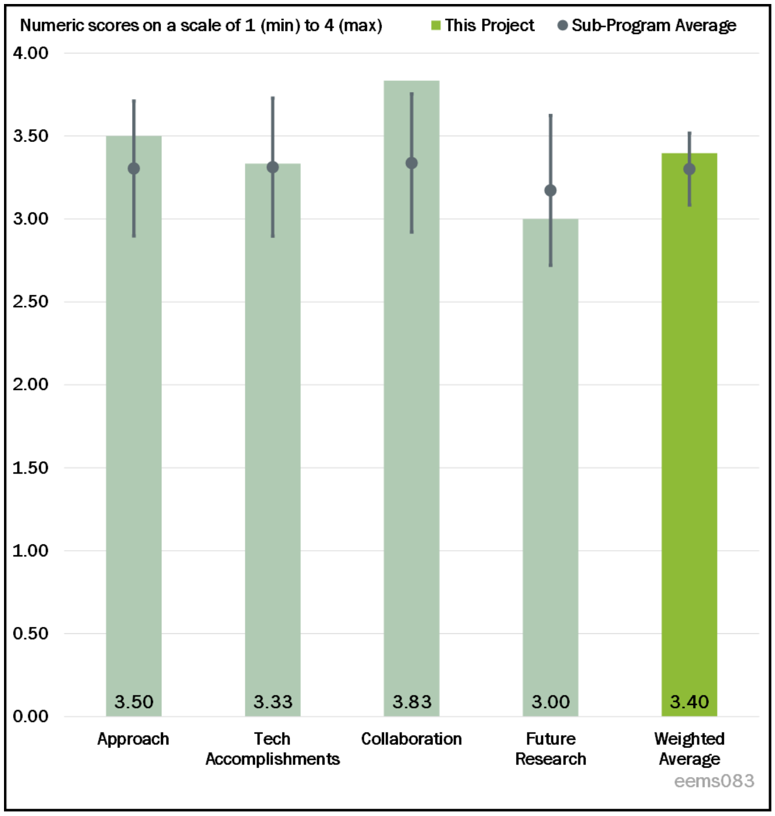

Figure 3-39 - Presentation Number: eems083 Presentation Title: CIRCLES: Congestion Impact Reduction via CAV-in-the-loop Lagrangian Energy Smoothing Principal Investigator: Alexandre Bayen (University of California at Berkeley)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project is well designed, but there are many undefined parameters and notable variability that need to be managed.

Reviewer 2:

The project design and approach are clearly laid out by technical category: traffic network modeling; Ordinary Differential Equation (ODE)/partial differential equation (PDE) and mean-field models; energy modeling; reinforcement-learning control algorithms; traffic data collection; test-bed development; and computer vision tracking algorithms. The presentation also addressed challenges and discussed future research plans and associated milestones.

Reviewer 3:

The overall approach appears to be very good. However, the reviewer still had some uncertainty with how the various components of the project fit together. A clearer description of the role of the infrastructure-collected data, the vehicle-collected data, and how they are used in the control strategy would be beneficial. The reviewer understood that the control strategies are being executed at the individual vehicle level, but it is still unclear if only their own sensors are being used for local data collection or if there are some high-level data that are also used in the vehicle control algorithms (e.g., current traffic volumes, speeds, etc.). The assumption can be made that the vehicle control is only controlling the longitudinal vehicle speed, but is it also controlling lane selection or lane changing? In summary, a clearer explanation of what is being developed is needed.

One of the challenges described is the difficulty in developing and calibrating a traffic simulation model that can realistically replicate the traffic waves (e.g., shockwaves). However, there does not seem to be a clear description of how this challenge will be overcome, or whether this project has the resources to overcome this challenge.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
This project started on January 1, 2020. According to the presenter and despite being a relatively new project, the project team has already completed more than 1,000 miles (by the time of audio recording for the presentation). The team appears to be on track for its five 2020 goals and laid out progress (e.g., designing relevant traffic macro-models) as well as next steps to help meet each of the outlined project goals.

Reviewer 2:
There appears to be excellent progress being made in this project. Development related to energy consumption models, vehicle-based data collection, and infrastructure-based data collection appears to be progressing well. The one challenge area that does not appear to have a clear solution path is the improvement of the traffic-flow models so that models can accurately replicate the traffic waves. This is a critical component to assess whether the vehicle-based control algorithm can actually “smooth” traffic.

Reviewer 3:
Overall, progress is being made, but some delays occurred due to COVID-19. There are still many unknown and details to finalize.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Each partner was identified with clear roles.

Reviewer 2:
The presentation clearly outlines ongoing collaboration and coordination with partner bodies, breaking up details by partner in a concise chart on one slide. The project team is also regularly coordinating. For instance, the team is working weekly with Toyota to expand the energy model inventory.

Reviewer 3:
The team appears to have excellent collaboration and coordination across its academic, industry, and government partners. All entities are contributing to the continued progress to date.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Milestones for proposed future research are clearly laid out for both FY 2020 and FY 2021. The milestones are somewhat generally described but clear. The team has also budgeted time to, for example, improve simulation boundary conditions.

Reviewer 2:
The project team needs to focus on how to solve for the unknowns to end up with understandable and usable results. Assumptions need to be confirmed to keep all data valid.

Reviewer 3:
The team appears to have a logical plan for moving forward with the research that incorporates go/no-go decision points related to critical milestones. If the development of a realistic traffic-flow model for" shockwaves" is a critical component to the assessment of this project, it would be good if the team were to develop some alternatives in the event that this is not attainable. Some of the other challenge areas, including "automatic detection and process of stop-and-go traffic" and "speed and accuracy of computer vision algorithms," appear to have alternative approaches that would involve more manual intervention or slower processing time, but could be used if necessary. This is based on the assumption that these processes are not used in "real time" vehicle-based control but are used in developing the control algorithms and assessing impacts on traffic flow "smoothing".

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Yes, this project is clearly focused on the use of CAV technologies to improve the energy consumption of vehicles. A lot of energy is wasted in stop-and-go traffic conditions, and this project aims to both reduce energy consumption for equipped CAVs and for these vehicles to act as a "smoothing" agent to other vehicles within the traffic stream. An additional benefit of the reduction of stop-and-go traffic conditions through traffic smoothing is the potential for reduced rear-end collisions, which have both safety, congestion, and energy impacts.

Reviewer 2:
Definitely, and If analyzed properly, the fuel savings effect for CAVs will be impactful and meet DOE objectives well.

Reviewer 3:
With the aim of helping to improve traffic flow and save energy, this project supports DOE's goal of supporting prudent development, deployment, and efficient use of energy resources.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Project resources seem to be well designed and sufficient. Each party has a clear role and communicates well.

Reviewer 2:
Funding seems generally sufficient. Calibration of demand, algorithm fine-tuning, and validation under varied conditions, etc., could always be further developed or expanded in future projects with additional funding later, if/once funding runs out.

Reviewer 3:
The resources appear to be sufficient; however, costs for a medium-scale test always have a risk of "cost creep."

Presentation Number: eems084
Presentation Title: Energy-Efficient Maneuvering of connected and Automated Vehicles (CAVs) with Situational Awareness at Intersections
Principal Investigator: Sankar Rengarajan (Southwest Research Institute)

Presenter

Sankar Rengarajan, Southwest Research Institute

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 25% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

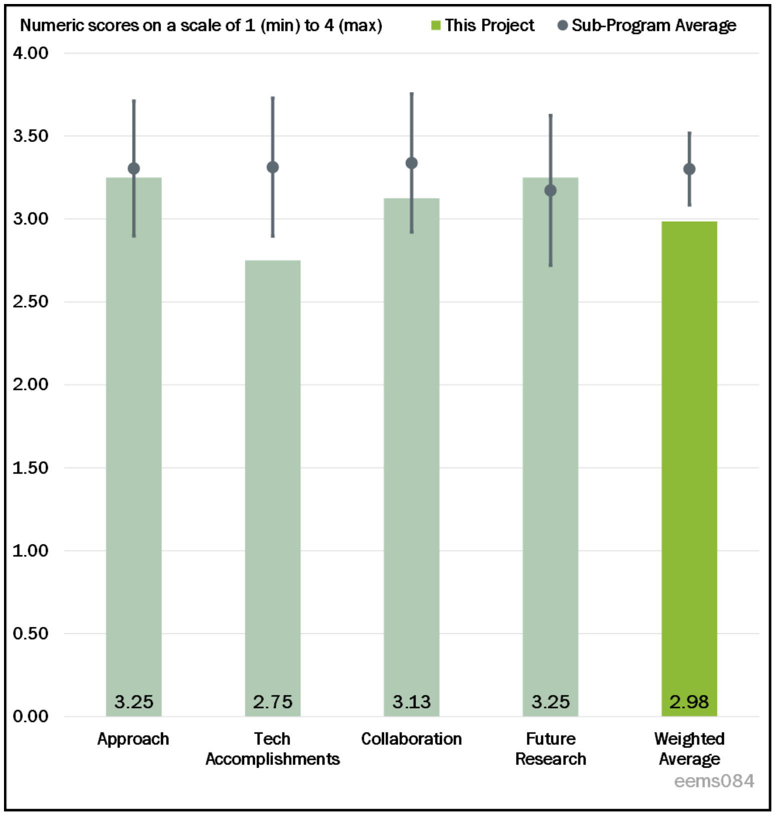

Figure 3-40 - Presentation Number: eems084 Presentation Title: Energy-Efficient Maneuvering of connected and Automated Vehicles (CAVs) with Situational Awareness at Intersections Principal Investigator: Sankar Rengarajan (Southwest Research Institute)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project has good experimental parameters, a nice selection of vehicles, simulation routes, and planned roadways for validation.

Reviewer 2:

The approach at the high level is appropriate and valid. The work recognizes the need to address realistic scenarios and validate to a wider range of conditions, including greater than 300 meters from the intersection. The work is feasible.

Reviewer 3:

The project outlines clear program objectives, milestones, and target outcomes. Challenges associated with simulation and related assumptions were addressed and responses to associated questions seemed generally reasonable. For example, the model does not assume a wide variation of vehicles; this means there are no tanker trucks. Rather, the vehicles are essentially assumed to be standard replications of existing vehicles, just with some driving “smart.” The presentation and project seem well laid out, with a good concept.

Reviewer 4:

The approach appears to be good overall, starting with simulation first, then following with a dynamometer integrated with simulation, and then finally a field test. This is a logical progression for the approach.

However, there was no real presentation of how some of the barriers and challenges will be addressed. For example, the system is relying on infrastructure-based detection of all vehicles, the majority of which will be "unconnected vehicles." The challenge was identified by the project team as "intersection stack validation with real data and long-range conditions (~300 meters from the intersection)." The accuracy of intersection-based detection equipment is significantly reduced at longer distances due to occlusion from other vehicles. This, in turn, will severely impact the ability of the eco-driving "speed optimization" to calculate appropriate speeds for the equipped vehicles. Approaches to overcome this challenge were not presented.

One item that could impact the performance of the system but was not mentioned in the presentation is the impact on how human drivers in "unconnected vehicles" will react to the "connected" vehicles that are driving based on optimized eco-driving speeds. These eco-driving "connected" vehicles have the potential to disrupt traffic and cause the drivers of the "unconnected" vehicles to behave differently and aggressively (e.g., changing lanes, speeding up, etc.). Be aware that current traffic simulation models will not take this behavior into account, so the results may not necessarily be realistic, especially at lower levels of market penetration of eco-driving vehicles.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
This project started on October 1, 2019, and is scheduled to run through the end of 2022. While the presenter mentioned that the team is still working on subcontracts and intellectual property (IP) agreements with partners, a 15% completion of progress to report is decent, particularly considering the events in the United States over the past several months and that the contract between DOE and the Southwest Research Institute was finalized fewer than 3 months ago on March 25, 2020. The team is on track with four of its FY 2020 milestones and has already started working on one of its FY 2021 milestones.

Reviewer 2:
The project was just approved 3 months ago, so not much significant work has been done. The team has a lot to finish in 2020 and 2021.

Reviewer 3:
This is a new project that is just underway, so not a lot of progress has been made yet. That said, the project appears to be on schedule. However, as mentioned above, it is not clear if progress has been made on coming up with possible solutions to some of the barriers and challenges that the project team has identified. Some of these potential solutions will likely need to be explored prior to the first go/no-go decision.

Reviewer 4:
The work, which is 15% complete, has not progressed sufficiently or met the key benchmarks and output to evaluate beyond this point. If work remains on track, the reviewer expected the rating to go up in subsequent reviews.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration appears to be excellent so far. The project team is hosting weekly calls to continue progress during COVID-19 times.

Reviewer 2:
The project has a good selection of partners with great synergies and capabilities.

Reviewer 3:
Subcontracts and IP agreements with partners were still being finalized. During this reporting period, the team has stayed connected through WebEx, as an example. The presentation lays out the distinct role and

partnership type for each collaborating partner organization. It is a bit early to fairly assess project-specific coordination with partners.

Reviewer 4:
Project collaboration is satisfactory. The effectiveness will be easier to evaluate after more time. The partners appear to be relevant and bring necessary contributions to the project. There appears to be some contradiction in the role of Continental; it is listed as facilitating meetings with Easy Mile, but also listed as providing the Level 4 vehicle. Please rectify the discrepancy and provide clear, consistent contributions from all partners and collaborators.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The project is well organized, considering its infancy stage. The reviewer would expect more detail as more is learned.

Reviewer 2:
The presentation clearly laid out plans for FY 2021 and FY 2022, with a transition from simulation to CAV dynamometer in FY 2021 and transition from dynamometer to track testing in FY 2022 (whereas FY 2020 is focused on simulation). The presentation and associated PowerPoint slides also discussed potential associated challenges. The reviewer noted that corridor selection for the traffic simulation is in progress. It is a challenge to accurately represent the real world, and the project team is working on this.

Reviewer 3:
Future research appears to be on track for the major milestones in FY 2020. Again, the project is fairly new so not a lot of progress has been made yet. The future milestone in FY 2021 of “intersection stack validated with real traffic data” has a barrier and challenge with respect to intersection-based sensing capabilities at longer distances (greater than 300 meters) that will need to be addressed. Understanding the accuracy of the sensor data at various distances, visibility conditions, traffic composition, etc., will be a key determinant in the system design and robustness.

Reviewer 4:
This question is not relevant because future work is this project’s formal work plan.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project aims to explore the potential benefit for eco-driving technology in a mixed fleet, potentially reducing energy consumption without negatively impacting trip times. This project supports DOE’s goal of promoting efficient use of energy resources and supporting a more economically competitive, environmentally responsible, secure, and resilient U.S. energy infrastructure.

Reviewer 2:
Yes, this project is very relevant, as it focuses on eco-driving for “connected” vehicles. Various vehicle powertrains and automation driving levels are being studied. Also, understanding the impact that a small percentage of “connected,” eco-driving vehicles will have on the majority of “unconnected” vehicles in the traffic stream will yield good insights.

Reviewer 3:
The project properly enumerated how the results align with DOE objectives.

Reviewer 4:
The project is using a mix of vehicles to confirm energy efficiency, which separates it from other projects. Also, the experiment to prove that even non-connected vehicles will have energy efficiency improvements is interesting and unique.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer believed project resources are the minimum needed to complete this project, but very good expertise exists in those selected.

Reviewer 2:
Funding seems generally sufficient to generate findings. For increased scope, scalability, etc., more resources later on could potentially help to further develop the project and findings (e.g., validating energy consumption benefits, etc.), if desired.

Reviewer 3:
Yes, resources appear to be sufficient.

Reviewer 4:
If the vehicles are provided by the partners, the $4 million or greater cost for a 2-year project appears high, given the tasks. While some of the cost will cover the chassis dynamometer testing, the indication is that much of the budget is for individual time. The reviewer expected more deliverables for the budget.

Presentation Number: eems086
Presentation Title: Simulation Tool for Energy-Efficient Connected and Automated Vehicle (CAV) Control Development
Principal Investigator: Dominik Karbowski (Argonne National Laboratory)

Presenter

Dominik Karbowski, Argonne National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

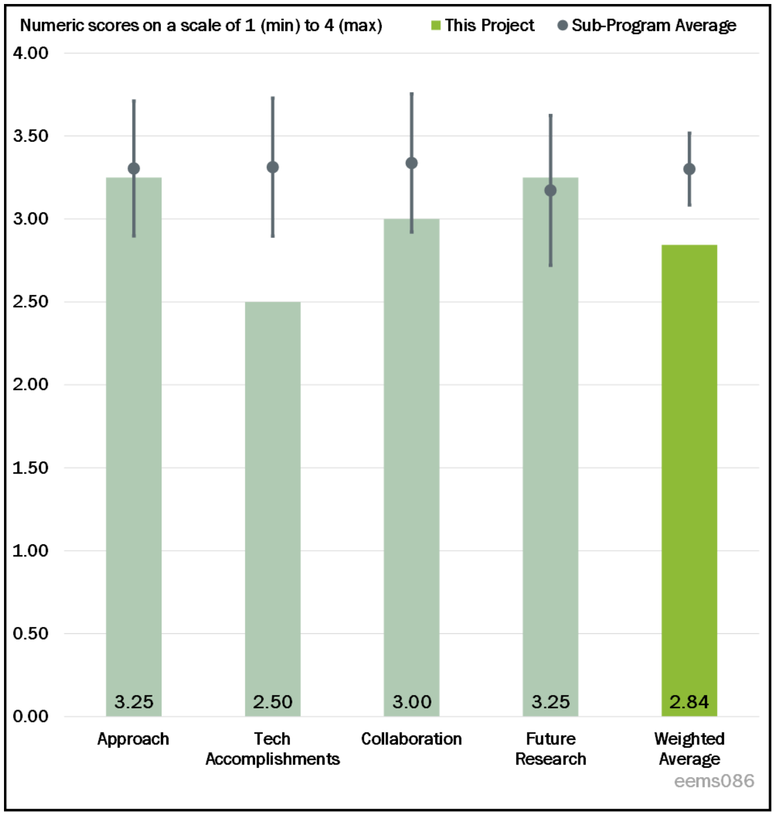

Figure 3-41 - Presentation Number: eems086 Presentation Title: Simulation Tool for Energy-Efficient Connected and Automated Vehicle (CAV) Control Development Principal Investigator: Dominik Karbowski (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project is clearly laid out with ample evidence (including earlier successful development and application of the RoadRunner tool)- that it will be successful in meeting the project purpose.

Reviewer 2:

The project seems feasible, with a lot in the hands of Hyundai Kia America Technical Center (HATCI) with respect to providing high-resolution temporal driving data to inform and validate the model. It is unclear how much of the driving trace data have already been shared. The reviewer saw that the data collection from the dedicated testing vehicle goes through the end of 2020, but it is not clear if the team is receiving data every month or only at the end. The reviewer also appreciated the variety in vehicle classes and types and hoped the team is able to show if there is a different type of driving depending on the vehicle class and type for comparison with future CAVs, or if the majority of the driving occurs due to different types of drivers (aggressive, calm, etc.).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The project has just started, so progress is slow. The reviewer suggested that the team work on alpha release and GUI. Additionally, the reviewer liked that ANL has already received some customer data and has been able to use innovative techniques to decipher what is happening during the trip—turning, intersection, entering and exiting the highway, etc.).

Reviewer 2:
It is early in the project, and milestone due dates are in the future. The presentation notes COVID-related delays in the start of on-road data collection.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Work is mainly between ANL and HATCI. It seems that the team is working well together and already sharing data. The first deliverable between the teams is in July 2020.

Reviewer 2:
The only partner is Hyundai, which has crucial roles in generating data and testing the RoadRunner tool.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The description of the future work is clear and sensible.

Reviewer 2:
Most of the work is left, but the plan to accomplish it seems logical and appropriate.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project supports DOE objectives well. It is specifically for the purpose of maximizing the energy savings of CAV technologies.

Commercialization of RoadRunner is an objective of the work. It would be desirable to ensure that this lab-developed product does not become cost prohibitive to the research community.

Reviewer 2:
Having a tool that enables the quantification and improvements of CAVs with respect to energy efficiency is relevant to DOE.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources seem reasonable for the project scope.

Reviewer 2:
There is no indication of insufficient funding.

Presentation Number: eems087
Presentation Title: Computation of Metropolitan-Scale, Quasi-Static Traffic Assignment Models Using High-Performance Computing
Principal Investigator: Jane Macfarlane (Lawrence Berkeley National Laboratory)

Presenter

Jane Macfarlane, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

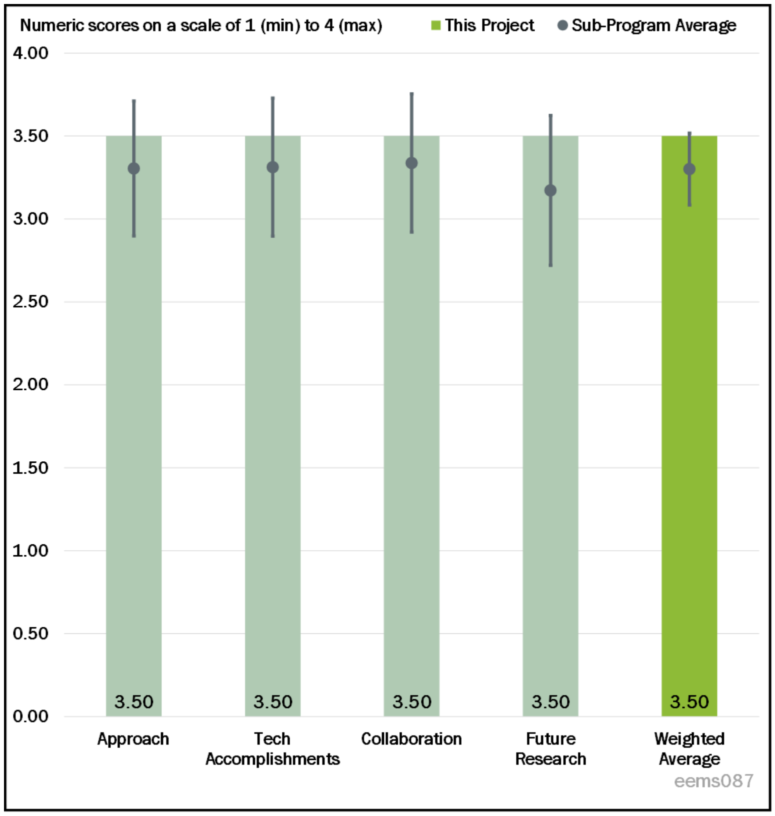

Figure 3-42 - Presentation Number: eems087 Presentation Title: Computation of Metropolitan-Scale, Quasi-Static Traffic Assignment Models Using High-Performance Computing Principal Investigator: Jane Macfarlane (Lawrence Berkeley National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project focused on HPC for assessing optimal energy use in metropolitan-scale transportation networks. The approach employed quasi-dynamic, parallel traffic assignment simulation comparing four cases involving user, system time, and fuel optimization. The researcher utilized an existing LBNL platform, Mobiliti, to facilitate the large-scale simulations.

Reviewer 2:

The project is well designed and is addressing current technical barriers.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The researcher stated that about 50% of the project scope has been completed as of the AMR presentation. The research appears to be on track for completion in fall 2020. Through utilization of the existing Mobiliti platform, significant progress has been achieved to date in deriving large-scale network results efficiently using HPC. The quasi-dynamic traffic assignment (QDTA) approach has yielded promising early optimization results for Bay Area simulations in terms of improved congestion flows and energy use. Results indicate that fuel-based optimization is very sensitive to speed profiles, and time-based optimization is sensitive to assumed time intervals.

Reviewer 2:
The team has generated impressive results, but in terms of reduced computational time and improvements of traffic flow on different parameters, it was unclear to the reviewer if the model output is sufficient for local traffic planners to improve traffic flow or if the team would also need to run the model as things change. If so, would the team need super computers, even with the computational optimization?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The researcher has exhibited good collaborative efforts across both government (e.g., the city of San Jose, the Southern California Association of Government [SCAG], and the San Francisco County Traffic Authority [SFCTA]) and industry organizations HERE Technologies, Uber) in terms of relevant database and information sources. The research also leveraged the use of an existing LBNL simulation platform, Mobiliti, for performing the work.

Reviewer 2:
It is clear that there is collaboration and coordination across the team and collaborators.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The researcher has laid out a reasonable plan for completing the work and meeting the original project objectives. The researcher plans further collaboration with the San Jose government to incorporate city sensor data and to validate the optimization models, which will be a critical next step. The researcher also plans to improve the adaptive learning functions and time intervals of the model for quicker convergence, especially for time-based optimization under high travel-demand periods. Finally, the researcher will translate QDTA results into training samples as a first step toward machine learning-based simulations for traffic management.

Reviewer 2:
Now that the project team has gotten this far, it makes sense to include travel modalities and to continue innovating with machine learning to address traffic-flow issues.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is relevant as it applies HPC to large-scale transportation network modeling and aims to support an eventual simulation framework for machine learning-based traffic congestion and energy use management.

Reviewer 2:
Improving the traffic flow increases mobility while decreasing energy, making the project very relevant to DOE goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The funding for this project seems sufficient for a 1-year project and the technical progress achieved.

Reviewer 2:
The budget allocated to this project seems reasonable, given the scope.

Presentation Number: eems088
Presentation Title: Chicago Transit Authority Transit Network Efficiency and the Changing Mobility Landscape
Principal Investigator: Joshua Auld (Argonne National Laboratory)

Presenter

Joshua Auld, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

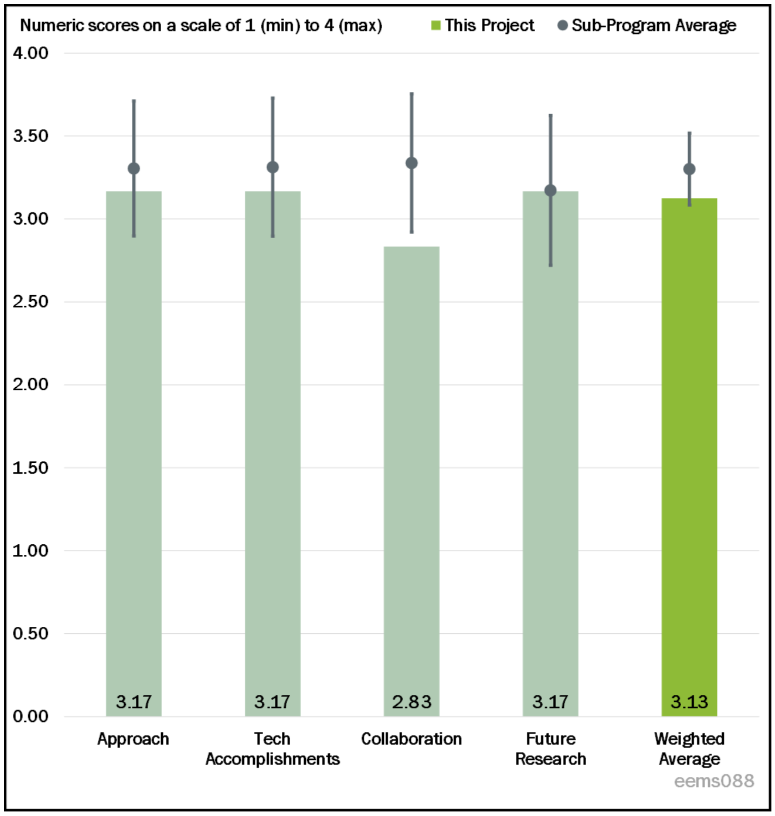

Figure 3-43 - Presentation Number: eems088 Presentation Title: Chicago Transit Authority Transit Network Efficiency and the Changing Mobility Landscape Principal Investigator: Joshua Auld (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project approach was well laid out and progressive involving collecting and analyzing data; developing transit frequency and a schedule optimization algorithm; and using POLARIS for large-scale transportation network scenario development and iterative modeling.

Reviewer 2:

How to reshape the future of transit service for improved mobility and energy resiliency is the primary research question this project aims to answer, at a high level. This includes potential reconfiguration of traditional transit services and potential integration (or competition) with new transportation modes, such as shared and electrified mobility.

The approach encompasses three primary steps: data analysis to determine significant factors impacting Chicago Transit Authority (CTA) ridership; open-loop implementation to develop optimization algorithms for identified targets and to simulate the optimized network in POLARIS; and closed-loop implementation to develop algorithms for identified targets and to simulate the optimized network in POLARIS through multiple scenarios and iterations.

Targets will be redefined as part of the open-loop simulations and subsequently combined with feedback from the CTA to test and evaluate hundreds of new scenarios. These efforts look to answer multiple questions through new algorithm development and modeling in POLARIS to identify new and modified routes, frequencies, timetables, electrified routes, and new strategies to improve performance. Closed-loop implementation will be similar to open-loop simulation but will be optimized using HPC.

This transit modeling emphasizes new CTA schedules integrated within a multi-modal algorithm framework. The project has identified three high-level barriers, including high uncertainty in technology deployment, functionality, usage, and system-level impact; complexity of the computational models, design, and simulation methodologies; and integration of many model frameworks, including land use, demand, flow, vehicles, grid, and economy.

Overall, the project is well designed, largely addresses key barriers, and is completely feasible.

Reviewer 3:
The research question of how to reshape the future of transit seems much broader than the research, which investigates optimization of scheduling and routing. Slide 6 indicates that an early step was analysis of factors impacting CTA ridership, including TNC level of service and price, but it is not clear how this analysis informed the research design.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
In spite of delays in getting an NDA signed with the project partner, significant progress was made on the 1-year project. The researcher stated that about 50% of the project scope has been completed as of the AMR presentation. The delay in the signed NDA resulted in delays in getting the actual transit data from CTA and their subsequent analysis. However, the researcher was able to complete the initial transit frequency and scheduling optimization algorithm and obtained preliminary results from POLARIS using simulation data to show increased boarding and reduced wait time. The researcher was also able to organize the workflow necessary for calibrating POLARIS with the CTA data and evaluating full scenarios using HPC. The project appears to be on track to completing the work by the end of FY 2020, as planned.

Reviewer 2:
The project achieved three significant technical accomplishments including solving the optimal transit frequency problem; integrating new schedules into POLARIS; and establishing the automated workflow for HPC implementation.

Strong, preliminary results have been achieved, including at a 5.1% increase in boardings and fare revenue, a 3.3% reduction in average waiting time, and a 22.4% decrease in rerouting due to missed connections or full vehicles (i.e., people are more satisfied with the new service). Technical analysis has also indicated the recommendation to shift the Chicago transit service to the outer and southern parts of the city.

Reviewer 3:
Results on boardings and wait time look reasonable and useful. There was a delay in model calibration due to an earlier delay in signing an NDA and obtaining data. However, the team did an analysis in the meantime with uncalibrated simulation data.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
ANL is the lead for this project, and the CTA is the sole partner, which is reasonable given the project emphasis and scope. CTA is providing data, setting goals, discussing results, and implementing agreed upon changes.

Reviewer 2:
The project has only one collaborator, which is the CTA. Although the NDA resulted in early delays for the project, the CTA provided relevant, in-depth data and information for the project and provides active feedback on results.

Reviewer 3:
CTA is the only partner, and their role is important (provide data, implement changes, etc.) but largely outside of the research itself.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Remaining challenges and barriers have been identified, including calibrating POLARIS to match CTA boarding and alighting counts and discussing preliminary results with CTA to obtain further guidelines. These are very reasonable and surmountable.

Proposed future activities include transit route design and redesign, transit frequency setting and timetabling, transit route electrification, and schedule adherence and performance improvement. It makes sense to further optimize POLARIS modeling to enhance the performance and energy efficiency of the CTA. If successful, which seems likely, it will lead to many benefits, including improved mobility, utilization, and revenue.

Reviewer 2:
The researcher's proposed future research will involve calibration of POLARIS using the CTA data and transit optimization scenario development and iterative evaluation using full-scale HPC. As part of the latter phase, the researcher plans to evaluate transit route design and redesign, transit frequency, transit bus route electrification, and transit schedule adherence and performance.

Reviewer 3:
Future work includes transit "performance improvement" beyond route design and scheduling, but the kind of improvement is not specified.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Yes, this project is very relevant as a result of the extreme disruption underway in the transportation system from vehicle electrification, shared mobility, e-commerce, automation, traveler behavior, and so forth, which provides new opportunities to improve transit performance and efficiency. Additionally, this effort has demonstrated it can lead to overall transit system performance and efficiency improvement, even without integration of new mobility options.

Reviewer 2:
The project is relevant in that it aims to evaluate the impacts of optimization of transit systems on large-scale transportation networks using HPC.

Reviewer 3:
Energy impacts are not shown as a direct output of the work. Presumably, the increase in boardings would save energy, but an explicit energy finding would be desirable in this multi-modal urban setting.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project resources are reasonable at $300,000 and appear sufficient to achieve the project's objectives.

Reviewer 2:
The funding for this project seems sufficient for a 1-year project and the technical progress achieved.

Reviewer 3:
There is no indication of insufficient funding. It looks as though the project is slightly behind schedule, but this is probably due to the delay in the NDA, which required a recalibration of the model to CTA data.

Acronyms and Abbreviations

21CTP	21st Century Truck Partnership
ACC	Adaptive cruise control
ACES	Automated, connected, electric and/or shared
ACM	American Center for Mobility
AEV	Autonomous electric vehicle
AFI	Advanced Fueling Infrastructure
AI	Artificial intelligence
AIMSUN	Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks
AMBER	Advanced Model Based Engineering Resource
AMD	Automated Mobility District
AMR	Annual Merit Review
ANL	Argonne National Laboratory
API	Application programming interface
AR	Augmented reality
ARPA-E	Advanced Research Projects Agency - Energy
ATM	Active traffic management
AV	Autonomous vehicle; Automated vehicle
BEAM	Behavior, Energy, Autonomy, and Mobility
BEV	Battery electric vehicle
CACC	Cooperative adaptive cruise control; coordinated adaptive cruise control
CARB	California Air Resources Board
CAV	Connected and autonomous vehicle
CARLA	Computer-Assisted Related Language Adaptation
CC	Cruise control
CRM	Coordinated ramp metering
CTA	Chicago Transit Authority
DCFC	Direct-current fast charging
DOE	U.S. Department of Energy

DOT	U.S. Department of Transportation
DPWT	Dynamic wireless power transfer
DTG	data.transportation.gov
EAD	Eco-approach and departure
eco-CAC	Eco-cooperated automated control
e-commerce	Electronic commerce
EEMS	Energy Efficient Mobility Systems
e-scooter	Electric scooter
EV	Electric vehicle
FAF	Freight Analysis Framework
FedEx	Federal Express
FHWA	Federal Highway Administration
F-MEP	Freight mobility energy productivity
FMLM	First-mile and last-mile
FOA	Funding Opportunity Announcement
FY	Fiscal Year
GM	General Motors
GPS	Global positioning system
GPU	Graphics processing unit
GUI	Graphical user interface
HATCI	Hyundai Kia America Test Center
HD	Heavy-duty
HIL	Hardware-in-the-loop
HPC	High performance computing
INL	Idaho National Laboratory
IP	Intellectual property
IT	Information technology
kW	Kilowatt

L2	Level 2
LBNL	Lawrence Berkeley National Laboratory
LD	Light-duty
LDP	LiveWire Data Platform
LDV	Light-duty vehicle
LLNL	Lawrence Livermore National Laboratory
LRRM	Local responsive ramp metering
MD	Medium-duty
MENNDL	Multi-node Evolutionary Neural Networks for Deep Learning
MEP	Mobility energy productivity
MIMO	Multi-input and multi-output
ML	Machine learning
MMIFE	Multi-modal intercity freight energy
MOD	Mobility-on-demand
MOTIVE	Mobility and Technology Insight Validation Evidence
mph	Miles per hour
MPO	Metropolitan Planning Organization
MTC	Metropolitan Transportation Commission
NDA	Non-disclosure agreement
NEXTCAR	Next-Generation Energy Technologies for Connected and Automated On-Road Vehicles
NGO	Non-governmental organizations
NHTSA	National Highway Traffic Safety Administration
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PI	Principal investigator
PNNL	Pacific Northwest National Laboratory
POLARIS	Planning and Operations Language for Agent-based Regional Integrated Simulation
Q	Quarter

Q&A	Question and answer
QDTA	Quasi-dynamic traffic assignment
RM	Ramp metering
SAV	Shared and automated vehicles
SFCTA	San Francisco County Transportation Authority
SIL	Software-in-the-loop
SMART	Systems and Modeling for Accelerated Research in Transportation
TNC	Transportation network company
TPO	Transportation Planning Organizations
U.S. DRIVE	U.S. Driving Research and Innovation for Vehicle efficiency and Energy sustainability
UPS	United Parcel Service
UrbanSim	Urban Simulation
V2X	Vehicle-to-anything
VIL	Vehicle-in-the-loop
VMT	Vehicle-miles traveled
VOTT	Value of travel time
VSA	Variable speed advisory
VTO	Vehicle Technologies Office
ZANZEFF	Zero and Near-Zero Emissions Freight Facilities

4. Electrification

The Vehicle Technologies Office (VTO) has a comprehensive portfolio of early-stage research to enable industry to accelerate the development and widespread use of a variety of promising sustainable transportation technologies. The research pathways focus on fuel diversification, vehicle efficiency, energy storage, and mobility energy productivity that can improve the overall energy efficiency and efficacy of the transportation or mobility system. VTO leverages the unique capabilities and world-class expertise of the National Laboratory system to develop innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures; and energy efficient mobility systems. VTO is uniquely positioned to address early-stage challenges due to strategic public-private research partnerships with industry (e.g., U.S. DRIVE, 21st Century Truck Partnership) that leverage relevant expertise. These partnerships prevent duplication of effort, focus DOE research on critical R&D barriers, and accelerate progress. VTO focuses on research that industry does not have the technical capability to undertake on its own, usually due to a high degree of scientific or technical uncertainty, or that is too far from market realization to merit industry resources.

The Electrification R&D effort focuses on early-stage research to support fast, secure, and resilient plug-in electric vehicle (PEV) charging on the nation's electric grid. Specifically, projects will increase the reliability of charging by focusing on smart-charging technology to support secure and cost-effective charging of large volumes of PEVs. Research will also focus on extreme fast-charging at power levels greater than 350 kW to support charging a PEV in 10–15 minutes and support heavy-duty truck charging as well. Impacts of PEV charging at scale for light-, medium-, and heavy-duty vehicles will be minimized through technologies that provide better flexibility and control, such as wireless charging approaches and chargers that use distributed energy resources, further supporting the Grid Modernization Initiative (GMI) and leveraging developments in battery energy storage technologies through the Behind the Meter Storage (BTMS) effort.

Electric Drive Research conducts R&D to reduce the cost of electric traction drive systems that can deliver at least 55kW of peak power to $7/kW by 2022, enabling cost-competitive technologies for vehicle electrification. Early-stage research focuses on extreme high-power density motor and power electronics technologies that have the potential to support radical new vehicle architectures by dramatic volume/space reductions and increased durability and reliability. This work emphasizes a 10-fold reduction in the volume of electric traction drive systems, which combine power electronics and motors using high-density integration technologies. Approaches include wide bandgap devices, dense power electronics packaging, novel circuit topologies, and new materials for high-density electric motors. Electric traction drive system integration based on power electronics and electric motor innovations are also be a priority.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0)*. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 4-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt089	Assessing the North American Supply Chain for Traction-Drive Inverters, Motors, and Batteries for Class 3-8 Hybrid Electric and Plug-In Electric Commercial Vehicles	Chris Whaling (Synthesis Partners)	4-10	3.00	3.00	3.13	3.00	**3.02**
elt091	Cost-Effective 6.5% Silicon Steel Laminate for Electric Machines	Jun Cui (Iowa State University)	4-13	2.88	2.63	2.88	2.75	**2.73**
elt115	Zero-Emission Cargo Transport I: Zero Emission Drayage Trucks	Phil Barroca (SCAQMD)	4-17	3.00	3.25	3.25	2.00	**3.03**
elt158	Zero-Emission Cargo Transport II: San Pedro Bay Ports Hybrid & Fuel-Cell Electric Vehicle Project	Seungbum Ha (SCAQMD)	4-19	3.00	2.00	2.00	2.00	**2.25**
elt187	Comprehensive Assessment of On- and Off-Board, Vehicle-to-Grid Technology Performance and Impacts on Batteries and the Grid (SPIN System)	Sunil Chhaya (EPRI)	4-21	3.25	3.00	3.38	2.75	**3.08**
elt188	Bi-Directional Wireless Power Flow for Medium-Duty, Vehicle-to-Grid Connectivity	Steven Sokolsky (CALSTART)	4-25	3.50	3.50	2.75	3.25	**3.38**
elt189	Electric Truck with Range-Extending Engine (ETREE)	Jesse Dalton (Cummins-Peterbilt)	4-27	3.60	3.40	3.50	3.38	**3.46**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt190	Medium-Duty Urban Range Extended Connected Powertrain (MURECP)	Matthew Thorington (Bosch)	4-31	3.33	3.33	3.50	3.00	**3.31**
elt191	Medium-Duty Vehicle Powertrain Electrification and Demonstration	Wiley McCoy (McLaren)	4-34	2.88	2.88	3.25	2.75	**2.91**
elt197	High Power and Dynamic Wireless Charging of Electric Vehicles	Veda Galigekere (ORNL)	4-38	2.75	3.13	3.00	2.63	**2.95**
elt198	Cybersecurity: Securing Vehicle Charging Infrastructure	Jay Johnson (SNL)	4-41	3.36	3.29	3.21	3.57	**3.33**
elt199	Cybersecurity: Consequence-Driven Cybersecurity for High-Power Charging Infrastructure	Richard Carlson (INL)	4-48	3.50	3.42	3.50	3.17	**3.42**
elt200	Scalable Electric Vehicle Smart Charging Using Collaborative Autonomy	Steve Chapin (LLNL)	4-53	2.88	2.75	2.50	2.63	**2.73**
elt201	Charging Infrastructure Technologies: Smart Vehicle-Grid Integration–ANL	Keith Hardy (ANL)	4-57	3.67	3.50	4.00	3.67	**3.63**
elt202	Charging Infrastructure Technologies: Smart Electric Vehicle Charging for a Reliable and Resilient Grid (RECHARGE)	Andrew Meintz (NREL)	4-60	3.50	3.33	3.67	3.33	**3.42**
elt204	Charging Infrastructure Technologies: Development of a Multiport, >1 MW Charging System for Medium- and Heavy-Duty Electric Vehicles	Andrew Meintz (NREL)	4-64	3.50	3.25	3.50	3.13	**3.33**
elt205	Cybersecurity for Grid-Connected Extreme Fast Charging Station (CyberX)	David Coats (ABB)	4-68	3.00	3.25	3.00	3.00	**3.13**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt206	Cybersecurity Platform and Certification Framework Development for Extreme Fast Charging, Integrated Charging, Infrastructure Ecosystem	Sunil Chhaya (EPRI)	4-70	3.50	3.38	3.63	3.13	**3.41**
elt207	Enabling Secure and Resilient Extreme Fast Charging: A Software/Hardware Security Co-Design Approach	Ryan Gerdes (Virginia Tech University)	4-74	3.00	2.67	2.50	2.67	**2.73**
elt208	Highly Integrated Power Module	Emre Gurpinar (ORNL)	4-77	3.50	3.38	3.75	3.63	**3.48**
elt209	High-Voltage, High-Power Density Traction-Drive Inverter	Gui-Jia Su (ORNL)	4-81	3.25	3.25	3.38	3.63	**3.31**
elt210	Development of Next-Generation Vertical Gallium-Nitride Devices for High-Power Density Electric Drivetrain	Greg Pickrell (SNL)	4-84	3.30	3.40	3.20	3.10	**3.31**
elt211	Power Electronics Thermal Management	Gilbert Moreno (NREL)	4-89	3.50	3.75	3.00	3.50	**3.56**
elt212	Non-Heavy Rare-Earth High-Speed Motors	Tsarafidy Raminosoa (ORNL)	4-93	3.00	3.00	3.00	3.13	**3.02**
elt213	High-Fidelity Multiphysics Material Models for Electric Motors	Jason Pries (ORNL)	4-96	3.10	2.90	3.20	3.10	**3.01**
elt214	Electric Motor Thermal Management	Kevin Bennion (NREL)	4-100	3.33	3.17	3.50	3.17	**3.25**
elt215	Permanent Magnets without Critical Rare Earths to Enable Electric Drive Motors with Exceptional Power Density	Iver Anderson (Ames Laboratory)	4-103	3.17	3.00	3.00	2.83	**3.02**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt216	Isotropic, Bottom-Up Soft Magnetic Composites for Rotating Machines	Todd Monson (SNL)	4-107	3.20	3.00	3.20	3.00	**3.08**
elt217	Integrated/Traction Drive Thermal Management	Bidzina Kekelia (NREL)	4-111	2.83	3.33	2.67	3.00	**3.08**
elt218	Advanced Power Electronics Designs–Reliability and Prognostics	Doug DeVoto (NREL)	4-114	3.50	3.67	3.83	3.50	**3.63**
elt219	Power Electronics Materials and Bonded Interfaces–Reliability and Lifetime	Paul Paret (NREL)	4-117	3.33	3.50	3.50	3.33	**3.44**
elt221	Integrated Electric Drive System	Shajjad Chowdhury (ORNL)	4-120	3.50	3.67	3.33	3.33	**3.54**
elt222	High-Reliability Ceramic Capacitors to Enable Extreme Power Density Improvements	Flicker, Jack (SNL)	4-122	3.67	3.67	2.83	3.67	**3.56**
elt223	Component Testing, Co-Optimization, and Trade-Space Evaluation	Jason Neely (SNL)	4-125	3.50	3.67	3.50	3.50	**3.58**
elt234	Soft Magnets to Achieve High-Efficiency Electric-Drive Motors of Exceptional Power Density	Matthew Kramer (Ames Laboratory)	4-127	2.90	2.90	2.80	2.70	**2.86**
elt236	Direct-Current Conversion Equipment Connected to the Medium-Voltage Grid for Extreme Fast Charging Utilizing Modular and Interoperable Architecture	Watson Collins (EPRI)	4-131	3.50	3.00	3.00	3.00	**3.13**
elt237	Enabling Extreme Fast Charging with Energy Storage	Jonathan Kimball (Missouri S&T)	4-133	3.00	3.50	3.00	2.50	**3.19**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt238	Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State Direct-Current Protection	Srdjan Lukic (North Carolina State University)	4-135	3.00	3.50	3.50	3.50	**3.38**
elt239	High-Power Inductive Charging System Development and Integration for Mobility	Omer Onar (ORNL)	4-137	3.83	3.67	3.50	3.33	**3.65**
elt240	Wireless Extreme Fast Charging for Electric Trucks (WXFC-Trucks)	Mike Masquelier (WAVE)	4-140	3.17	2.83	3.17	3.00	**2.98**
elt241	High-Efficiency, Medium-Voltage Input, Solid-State, Transformer-Based 400-kW/1000-V/400-A Extreme Fast Charger for Electric Vehicles	Charles Zhu (Delta Electronics)	4-143	3.38	3.50	3.38	3.38	**3.44**
elt242	Heterogeneous Integration Technologies for High-Temperature, High-Density, Low-Profile Power Modules of Wide Bandgap Devices in Electric-Drive Applications	G.Q. Lu (Virginia Tech University)	4-147	3.25	3.00	3.50	3.50	**3.19**
elt243	Integrated Motor and Drive for Traction Applications	Bulent Sarlioglu (University of Wisconsin)	4-149	3.50	3.50	3.33	3.50	**3.48**
elt244	Next-Generation, High-Temperature, High-Frequency, High-Efficiency, High-Power Density Traction System	Robert Pilawa (University of California at Berkeley)	4-151	3.50	3.17	2.83	3.00	**3.19**
elt245	Integration Methods for High-Density Integrated Electric Drives	Alan Mantooth (University of Arkansas)	4-154	3.13	3.25	3.25	3.25	**3.22**
elt246	Implementation of Wide-Bandgap Devices in Circuits, Circuit Topology, System Integration as well as Silicon Carbide Devices	Anant Agarwal (Ohio State University)	4-157	3.00	3.25	2.75	3.00	**3.09**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt247	Cost-Competitive, High-Performance, Highly Reliable Power Devices on Silicon Carbide and Gallium Nitride	Woongje Sung (State University of New York Polytechnic Institute)	4-159	3.67	3.33	3.17	3.50	**3.42**
elt248	Multi-Objective Design Optimization of 100-kW Non-Rare-Earth or Reduced-Rare Earth Machines	Scott Sudhoff (Purdue University)	4-162	2.50	2.75	3.00	2.50	**2.69**
elt249	Rugged Wide Bandgap Devices and Advanced Electric Machines for High-Power Density Automotive Electric Drives	Victor Veliadis (North Carolina State University)	4-164	4.00	4.00	4.00	4.00	**4.00**
elt250	Design, Optimization, and Control of a 100-kW Electric Traction Motor Meeting or Exceeding DOE 2025 Targets	Ian Brown (Illinois Institute of Technology)	4-166	2.00	2.00	2.50	2.00	**2.06**
elt251	Device- and System-Level Thermal Packaging for Electric-Drive Technologies	Yogendra Joshi (Georgia Institute of Technology)	4-168	3.33	3.50	3.00	3.17	**3.35**
elt252	Wound-Field Synchronous Machine-System Integration toward Increased Power Density and Commercialization	Lakshmi Iyer (Magma Services of America, Inc.)	4-170	2.00	2.00	3.00	2.00	**2.13**
elt253	Motor with Advanced Concepts for High-Power Density and Integrated Cooling for Efficiency Machine	Jagadeesh Tangudu (United Technologies Research Center)	4-172	2.67	2.50	2.50	2.50	**2.54**
elt254	Ultra-High Speed, High-Temperature Motor	Joseph Lyding (University of Illinois at Urbana-Champaign)	4-175	2.33	2.17	2.50	2.00	**2.23**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt255	Cost-Effective, Rare-Earth-Free, Flux-Doubling, Torque-Doubling, Increased Power Density Traction Motor with Near-Zero Open-Circuit Back-Electromagnetic Field and No-Cogging Torque	Soma Essakiappan (University of North Carolina at Charlotte)	4-179	2.83	2.50	2.67	3.00	**2.67**
elt256	Amorphous Metal Ribbons and Metal Amorphous Nanocomposite Materials Enabled High-Power Density Vehicle Motor Applications	Mike McHenry (Carnegie Mellon University)	4-182	2.67	2.50	2.83	2.67	**2.60**
elt257	Directed Electric Charging of Transportation using eXtreme Fast Charging (XFC) (DIRECT XFC)	Tim Pennington (INL)	4-185	3.00	3.00	2.67	2.83	**2.94**
elt258	Grid-Enhanced, Mobility-Integrated Network Infrastructures for Extreme Fast Charging (GEMINI-XFC)	Matteo Muratori (NREL)	4-189	2.33	2.67	2.33	2.50	**2.52**
elt259	Development and Commercialization of Heavy-Duty Battery Electric Trucks Under Diverse Climate Conditions	Marcus Malinosky (Daimler Trucks North America)	4-193	3.25	3.42	3.50	3.25	**3.36**
elt260	Improving the Freight Productivity of a Heavy-Duty, Battery Electric Truck by Intelligent Energy Management	Teresa Taylor (Volvo)	4-198	3.25	3.25	3.42	3.25	**3.27**
elt261	High-Efficiency Powertrain for Heavy-Duty Trucks using Silicon Carbide Inverter	Ben Maruqart (Ricardo)	4-203	2.88	3.00	3.00	2.88	**2.95**
elt262	Long-Range, Heavy-Duty Battery-Electric Vehicle with Megawatt Wireless Charging	Brian Lindgren (Kenworth)	4-207	3.07	3.21	3.29	3.07	**3.17**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt263	Cybersecurity: Securing Vehicle Charging Infrastructure - Consequence Analysis and Threat Assessment	Rick Pratt (PNNL)	4-212	3.25	3.25	3.00	3.25	**3.22**
Overall Average				**3.19**	**3.16**	**3.17**	**3.08**	**3.16**

Presentation Number: elt089
Presentation Title: Assessing the North American Supply Chain for Traction-Drive Inverters, Motors, and Batteries for Class 3-8 Hybrid Electric and Plug-In Electric Commercial Vehicles
Principal Investigator: Chris Whaling (Synthesis Partners)

Presenter

Chris Whaling, Synthesis Partners

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

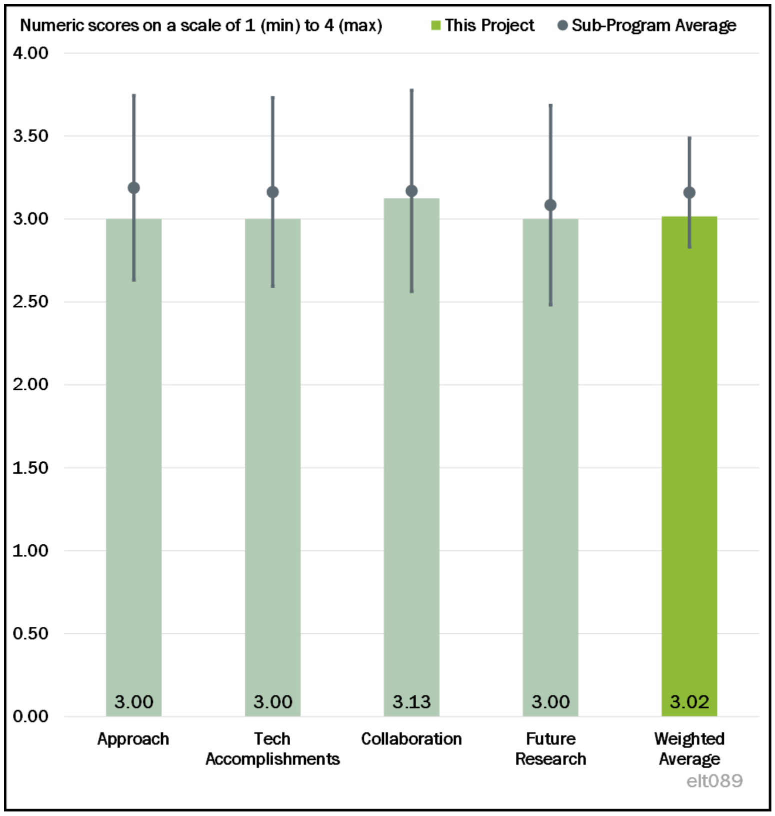

Figure 4-1 - Presentation Number: elt089 Presentation Title: Assessing the North American Supply Chain for Traction-Drive Inverters, Motors, and Batteries for Class 3-8 Hybrid Electric and Plug-In Electric Commercial Vehicles Principal Investigator: Chris Whaling (Synthesis Partners)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The approach seems systematic and comprehensive.

Reviewer 2:
The approach includes logical steps; namely, data collection from primary and secondary sources followed by modeling of data and application of data analytics tools. Outcome of data analysis allows the project team to identify gaps. Key findings are included in the report. Fiscal Year (FY) 2019 findings are included in the report released to the public. This is an iterative process and a work in progress.

Reviewer 3:
It appears from the presentation that the majority of effort has focused on current state of the North American (NA) supply chain which addresses a barrier. Little information was presented on actionable intelligence for research and development (R&D) opportunities which should be of significant interest to the Vehicle Technologies Office (VTO) moving forward.

Reviewer 4:
Traction drive rare earth (RE) magnets are critical elements of which the majority of the current supply are controlled by a single country. Accessing the supply chain is very crucial for future R&D planning. It will be a value add to compare the cost and performance of heavy rare earth (HRE) magnets with reduced HRE magnets

versus HRE free magnets. The roadmap of these three technologies will decide the cost of the RE magnets too. This factor has to be taken into account in the model that is developed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The data collection method was clearly understood and implemented to understand gaps. Primary sources and contacts (hierarchy in source company) are categorized in the project report. The 2019 outlook of RE material mining from United States (U.S.) mines and global mines is stated in project report. Global distribution of RE reserves is provided in a bar chart. Price trends of RE are provided for the period of 20102019. RE oxides' average annual prices for the duration of 2015-2019 are outlined in the project report. U.S. government's RE stockpiles are outlined in the project report using a pie chart. For 2017, RE element applications are provided in the project report using a pie chart. For 2021, RE element applications are shown in the project report. Pie-chart based data visualization is quite easy to understand. Key RE supply chain bottlenecks are identified. Electric vehicle (EV) demand outlooks up to 2030 are provided in the report. In addition to the above, many outlooks are provided for various aspects of RE, oxides, and magnets.

Reviewer 2:
This project has tried to consolidate information about the current state of RE traction drive magnets and their supply chains in North America. Also, intelligence on R&D opportunities that can help strengthen RE supply chains, EVs, and autonomous vehicles in North America has been presented.

Reviewer 3:
There is reasonable progress made but the significance of the findings is not very clear.

Reviewer 4:
Considerable progress has been made in providing accurate information on the current state of the NA supply chain.

Progress against actionable intelligence on R&D opportunities appears limited from the presentation. This is supposed to be addressed in the January - April 2020 period.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There was good collaboration with multiple entities.

Reviewer 2:
The project is led by Christopher Whaling in Synthesis Partners, LLC. For data collection, hundreds of contacts and touchpoints were made.

Reviewer 3:
In this project, efforts have been made to interact with numerous original equipment manufacturers (OEMs), Tier 1-4 suppliers, R&D organizations, universities, United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE) Electrical & Electronics Tech Team members, the National Renewable Energy Laboratory (NREL) and Oak Ridge National Laboratory (ORNL).

Reviewer 4:
It appeared to the reviewer that there were Interactions with industry, universities, and National Laboratories as well as significant effort within primary and secondary research organizations.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Potential pathways to NA RE-to-magnet supply chain renewal is included as a topic for future research, which is quite relevant.

Reviewer 2:
This is not a R&D project and no future research was proposed. The reviewer expects that this project will provide insight for future R&D opportunities.

Reviewer 3:
The go/no-go decisions were well in the past. The reviewer noted this project is about to end in about 3 months.

Reviewer 4:
The proposed future research and its significance are not very clear.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
RE supply chain assessment is very critical to plan future technologies and national security. The project supports U.S. Department of Energy (DOE) objectives very well.

Reviewer 2:
Understanding the RE market is critical moving forward.

Reviewer 3:
It is extremely relevant to know gaps in the supply chain of RE materials and magnets made thereof. Then, addressing RE materials supply chain gaps by carrying out targeted R&D project works. This project has the potential to support DOE-VTO in setting direction for future funding; therefore, this project and its findings may indirectly become quite relevant to DOE-VTO objectives and goals.

Reviewer 4:
This project supports the DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Team is well organized with credible results presented.

Reviewer 2:
Project has necessary resources and funding to be successful.

Reviewer 3:
Based on the level of effort, the resources seem to be sufficient.

Reviewer 4:
From the presentation and principal investigator's (PI's) comments, the project is expected to be completed within the proposed timeline and no additional resources are required.

Presentation Number: elt091
Presentation Title: Cost-Effective 6.5% Silicon Steel Laminate for Electric Machines
Principal Investigator: Jun Cui (Iowa State University)

Presenter

Jun Cui, Iowa State University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

75% of reviewers indicated that the project was relevant to current DOE objectives, 25% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers indicated that the resources were sufficient, 25% of reviewers indicated that the resources were insufficient, 25% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

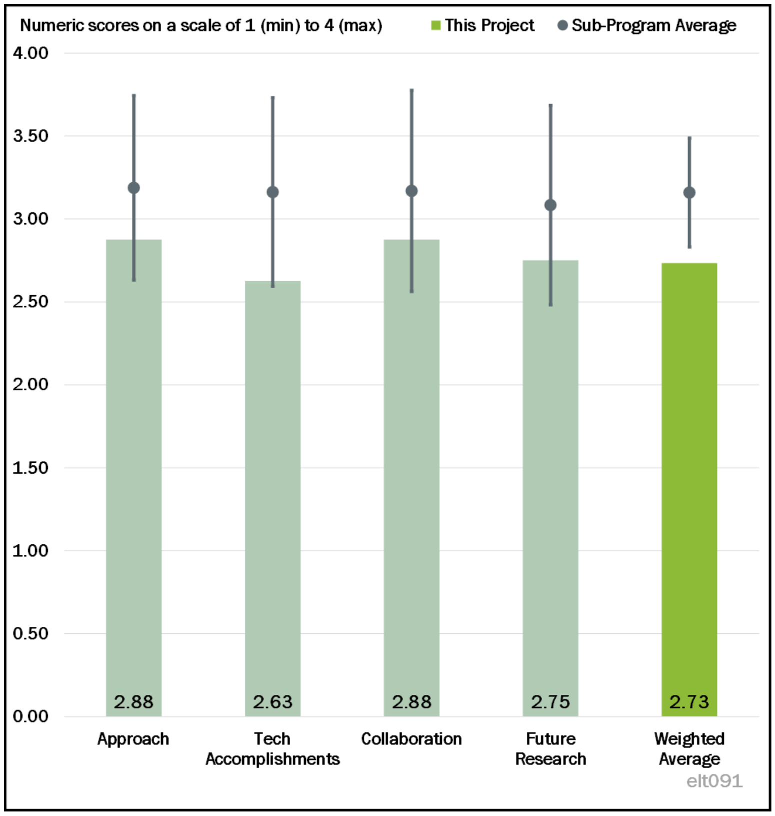

Figure 4-2 - Presentation Number: elt091 Presentation Title: Cost-Effective 6.5% Silicon Steel Laminate for Electric Machines Principal Investigator: Jun Cui (Iowa State University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

It appears that the barriers are well understood.

Reviewer 2:

The reviewer was not familiar with the specifics of the metallurgical processes, but the approach seemed systematic and good progress was made.

Reviewer 3:

The reviewer is concerned about the scaling of hot press consolidation of the 6.5% silicon (Si) flakes. Is the hot press consolidation realistic for high volume production parts? The reviewer thought it depends how long the hot press process takes. The consolidation step to form a near net shape part concerns this reviewer in terms of the size of features that can be created or the overall size of the consolidated stack. This reviewer wished that this step had been examined more as part of the project.

Reviewer 4:

The reviewer's understanding from the presentation is that a new material has been developed but the presentation does not address any of the DOE targets that have been highlighted in Slide 2 (Cost and Power Density). As the project team states, the flux density of the 6.5% Si steel is much less when compared to conventional Si steel. Also, if the claim is reducing core loss at high frequencies, then a comparison of the state-of-the-art Si steel (used in automotive industry) should be compared with this 6.5% Si steel for flux density, core loss at different frequencies, and mechanical and tensile strength properties. The similar holds true for the manganese bismuth (MnBi) based non-RE magnet. A comparison of this magnet with a N42EH (for example or any other magnets which are widely used in the auto industry) must be compared for magnetic flux density and magnetic field strength (B-H) characteristics at 20 degrees Celsius (°C), 100°C, 150°C, 180°C and 200°C.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project is well on track.

Reviewer 2:
Good technical accomplishments have been made. While it appears that the MnBi coercivity increases with temperature in the plot on Slide 6, the romance appears to have a substantial drop. It is unclear if the overall energy product is increasing or decreasing with temperature. The rate of change with temperature is also unclear. It would be useful to compare these magnets to ferrite and automotive-grade neodymium iron boron (NdFeB). It is unclear how the calcium fluoride (CaF_2) insulation layer compares to standard C5 lamination insulation. The electrical resistivity versus melt spun wheel speed seems to have quite a wide error bar for some wheel speeds but not for others. The forsterite (Mg_2SiO_4) insulation coating appears to be very interesting.

Reviewer 3:
There is good progress made but it is not clear to this reviewer that the accomplished material properties and the test results of the prototype motor provide a path to meeting the DOE targets or surpassing the current state-of-the-art. There are some significant differences between predicted and measured results. The power density is far from the DOE targets. Also, the improvement in measured efficiency is not very clear. Lastly, more results around permanent magnets demagnetization should have been included.

Reviewer 4:
It is very difficult to understand how the magnet material, with much less energy density, and the 6.5% Si steel, with much less flux density and questionable core loss (as there is no comparison of core loss versus frequency between this steel and the conventional Si steel used in auto industry), will meet the DOE cost and power density targets. With limited time available in this project, it is very uncertain that the project objectives will be met.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There is good collaboration in terms of materials development and integrating the new materials into a motor prototype and testing it.

Reviewer 2:
The coordination among the team partners appears to be good.

Reviewer 3:
The reviewer could not fairly assess from the slides, but the work seems to be well coordinated.

Reviewer 4:
Collaboration with OEMs, magnet suppliers, and steel suppliers would have been a big plus, which would have driven the project to attain the project goals in a timely fashion.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The remaining barriers are really to scale the developed flake production processes for the magnet and 6.5% Si steel. This is a critical step and still quite high risk as the production of samples for this project were quite low in volume. It is encouraging that the project knowledge is being passed to Metglas who might scale it up and commercialize it.

Reviewer 2:
The project will be ending soon. This reviewer highly recommended continuation.

Reviewer 3:
This reviewer thought the proposed future research will require significant amount of resources and the path to meeting the DOE targets or surpassing the state-of-the-art is not clear.

Reviewer 4:
Based on the presentation it is very unclear how the technical barriers have been met or will be met. Can the project team compare the motor built (using the magnet and steel material developed), with an off-the-shelf electric machine (considering the stator diameter, stack length, voltage input, root mean square (RMS) current inputs, cooling, duty cycle all being the same), and claim that this motor can deliver much higher power density and efficiency with less cost?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This reviewer described the project as one of the critical technologies for energy security.

Reviewer 2:
The development of a cost effective 6.5% silicon steel would be beneficial for the development of high-speed electrical machinery and the management of their losses. Increasing the ductility of the 6.5% silicon steel is also important. The work on MnBi magnets is also good, as a lower cost magnet alternative with a reasonable energy product would be a great alternative.

Reviewer 3:
It is relevant but it is not clear that it provides a clear path to meeting the DOE targets.

Reviewer 4:
The motor built with the materials developed in this project is going to give much lower torque density, power density, and efficiency and cost more.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project seems to be on track.

Reviewer 2:
About 90% of the project is done and the project seems to be wrapping up.

Reviewer 3:
It appears that the project partners mostly have sufficient resources for the completion of the project and milestones. The reviewer was concerned that some of the final milestones were not met and it is not clear if that was due to resource restrictions.

Reviewer 4:
Without support from OEMs and magnet and steel suppliers, it is very vague how the objectives can be met with the current resources.

Presentation Number: elt115
Presentation Title: Zero-Emission Cargo Transport I: Zero Emission Drayage Trucks
Principal Investigator: Phil Barroca (South Coast Air Quality Management District)

Presenter

Phil Barroca, South Coast Air Quality Management District

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

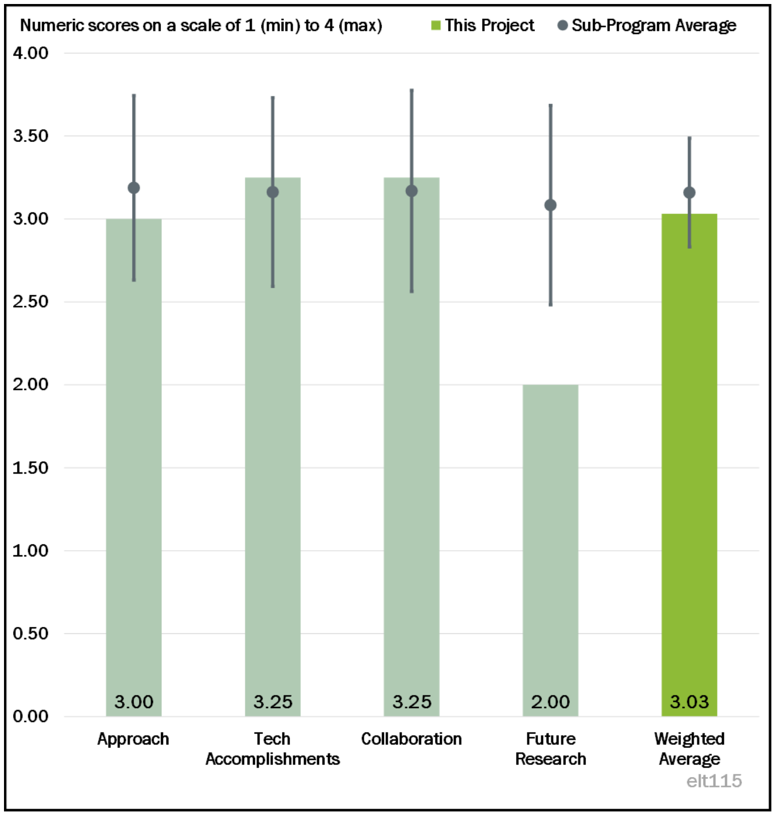

Figure 4-3 - Presentation Number: elt115 Presentation Title: Zero-Emission Cargo Transport I: Zero Emission Drayage Trucks Principal Investigator: Phil Barroca (South Coast Air Quality Management District)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Laboratory work is important for development of new technologies, but successful demonstration in the field is the key element in commercialization. It is only by actually building and operating different types of trucks in the real world that experimental vehicles can be appropriately evaluated. This project did a very good job showing that electric drayage trucks could really work.

Reviewer 2:

The approach of testing the feasibility of all electric trucks using four platforms (two battery-electric and two plug-in electric) was a good idea. Certainly, the test site was a good choice: Ports of Los Angeles and Long Beach, the largest ports in the United States and also the most needed locations because they are in a non-attainment area and of concern to neighboring ethnic minority disadvantaged communities.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Several different configurations were built and successfully operated under real-world conditions. Difficulties were identified and designs updated to overcome them. Results were clearly presented and will enable manufacturers and users to move forward. The reviewer would like to have seen a bit of discussion on which types of trucks were most likely to be successful in which types of operations, and what types of locations.

Reviewer 2:
The objectives could have clearer in specifying whether this was a proof-of-concept, exploratory, or otherwise a specific type of demonstration. The reviewer was expecting certain quantitative rather than qualitative goals and objectives to be specified at the onset. Also, it did not seem that the PI started out using the best state-of-the-art equipment, especially batteries. The PI needs to identify the particular problems besetting or preventing the use of all-electric drive trucks for drayage. For example, is it range? Is sufficient energy density storage a problem or something else? Another problem is that the PI was not using common units to compare fuel efficiency or fuel economy to allow for apples-to-apples comparison instead of apples-to-oranges comparison.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This project required and achieved successful collaboration from a set of diverse industries, ranging from battery manufacturers to truck manufacturers to shippers. Without close collaboration, demonstrations could not have been achieved successfully.

Reviewer 2:
The reviewer did not have confidence that the project team looked at the best choices for the selection of electric batteries.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The project is essentially complete.

Reviewer 2:
The reviewer really did not see much proposed future research in the area of all-electric drive trucks for drayage until a near-order-of-magnitude improvement in battery energy storage takes place. Otherwise, the reviewer thought it would not be of value.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Drayage trucks are a significant fuel user and source of emissions in crowded port areas. There is a big opportunity to clean up our ports and reduce our use of diesel fuel if these trucks can be economically converted to alternative energy sources.

Reviewer 2:
Yes. It is necessary to examine all areas of transportation, including heavy-duty freight movement over the road to make sure all possible improvements in energy use are made.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Without sufficient resources, the project team could not have invested the time required to design and redesign and build these trucks.

Reviewer 2:
The reviewer thought more than enough money was spent answering the question of whether all-electric drive trucks for drayage is feasible. This is an area not as suitable as, say, local pick-up and delivery.

Presentation Number: elt158
Presentation Title: Zero-Emission Cargo Transport II: San Pedro Bay Ports Hybrid & Fuel-Cell Electric Vehicle Project
Principal Investigator: Seungbum Ha (South Coast Air Quality Management District)

Presenter

Seungbum Ha, South Coast Air Quality Management District

Reviewer Sample Size

A total of one reviewer evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

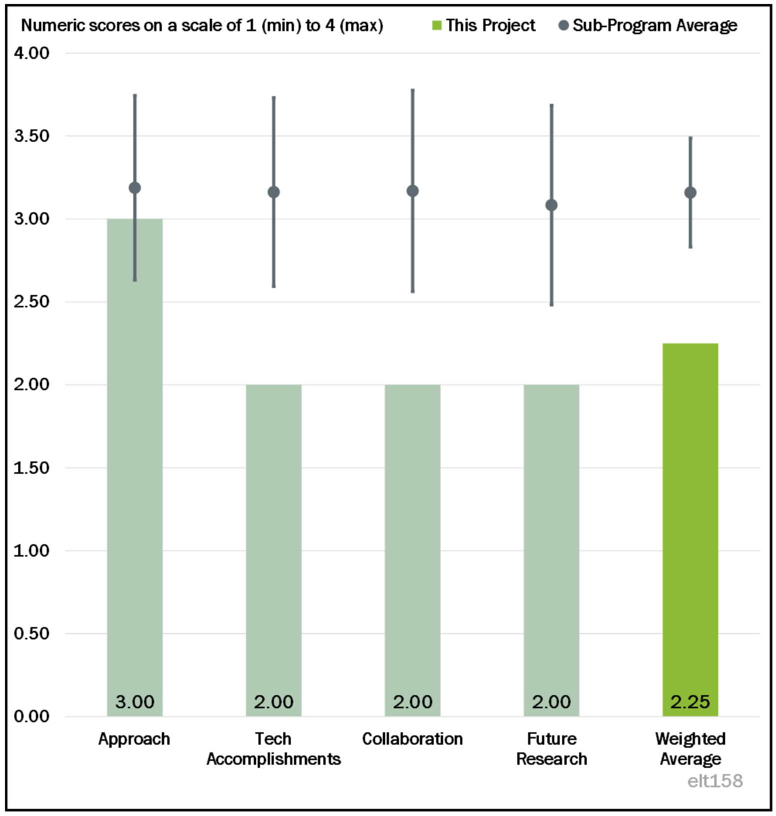

Figure 4-4 - Presentation Number: elt158 Presentation Title: Zero-Emission Cargo Transport II: San Pedro Bay Ports Hybrid & Fuel-Cell Electric Vehicle Project Principal Investigator: Seungbum Ha (South Coast Air Quality Management District)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer did not think the goals and objectives of this project were defined well enough for anyone from the outside to decide whether the approach is good or not. There were no quantitative goals and objectives, so the reviewer wondered if this project is to just gather as much data as possible? If so, what is the purpose of gathering the data? Or is this a project to test feasibility of zero-emission range-extenders for drayage trucks? Or is the purpose to test feasibility of hydrogen fuel cells as an energy source for drayage trucks? Compressed natural gas (CNG) or liquefied natural gas (LNG) is perfectly suitable for use in auxiliary power units (APUs) for range extenders. It was not made clear how Zero-Emission Cargo Transport II (ZECT II) differs from ZECT I. Both are electric but it seems ZECT II relies on hydrogen.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer was not happy at all that there were a lot of practical low-technology problems not even related to hydrogen fuel cells that have bedeviled the project, such as finding out the most optimum batteries for energy storage were not used at the beginning. Especially daunting to this reviewer was repeated failure of critical software updates, battery disconnects, power steering fluid pumps, motor inverters, traction motor resolver, transmission shift sensors, fuel cell coolant contamination, thermal management systems, and layout and packaging of components on the truck chassis, which should have been caught in the design stage rather than in testing. Most of the resources seems to have gone into addressing these "minor" problems.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team did not look well enough into analyzing and comparing different sources of hydrogen, such as: portable methane reformation (the largest natural gas filling station in the United States is located in Wilmington at or near the border between the Cities of Los Angeles and Long Beach); sharing with hydrogen fueling stations already in place for other vehicles, such as in Torrance, California; and hydrogen being used by neighboring oil refineries (hydrogen is being used to hydrogenate or convert many alkynes and alkenes to alkanes).

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
A significant problem seems to be electric energy storage and the evolving nature of battery management systems. Until electric batteries are vastly improved, the reviewer would not fund any further research on ZECT II. While proof-of-concept or feasibility testing is worthwhile, the reviewer did not see future research on hydrogen fuel cells for drayage trucks as worthwhile until the cost of generating hydrogen drops and becomes competitive with fossil fuels. In the meantime, natural gas is a cleaner fuel than diesel fuel and could serve as a replacement for diesel fuel until hydrogen fuel cell technology and the cost of hydrogen both make hydrogen fuel cell trucks appropriate and relevant.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
It is important to examine every possible nook and cranny for potential uses of hydrogen fuel cell to reduce fossil fuel consumption, climate change impacts, and improve energy security.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer questioned the team’s project execution.

Presentation Number: elt187
Presentation Title: Comprehensive Assessment of On- and Off-Board, Vehicle-to-Grid Technology Performance and Impacts on Batteries and the Grid (SPIN System)
Principal Investigator: Sunil Chhaya (Electric Power Research Institute)

Presenter

Sunil Chhaya, Electric Power Research Institute

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

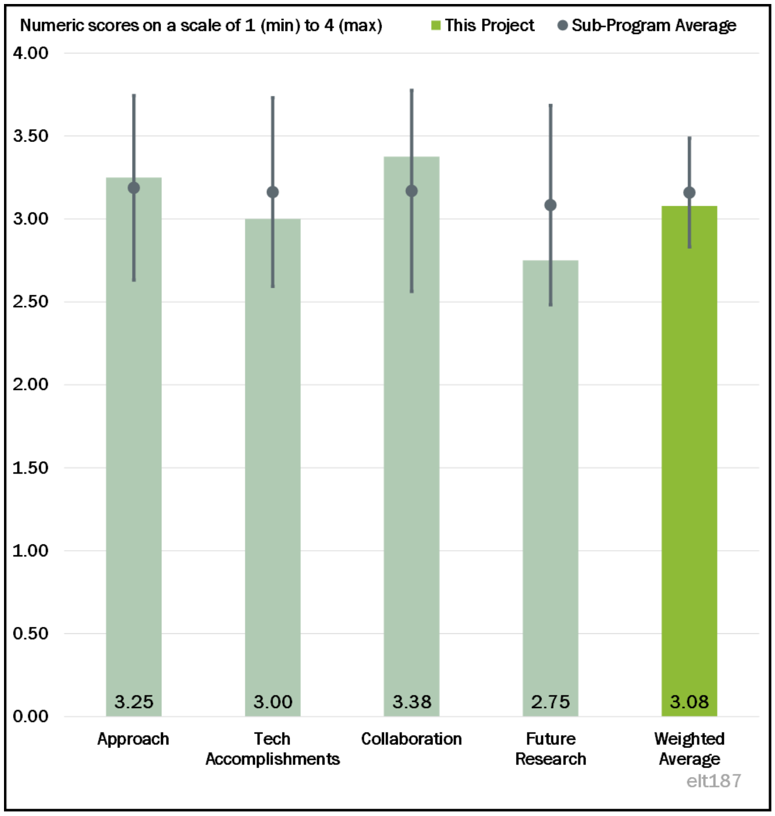

Figure 4-5 - Presentation Number: elt187 Presentation Title: Comprehensive Assessment of On- and Off-Board, Vehicle-to-Grid Technology Performance and Impacts on Batteries and the Grid (SPIN System) Principal Investigator: Sunil Chhaya (Electric Power Research Institute)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The technical approach addresses the project objectives in a reasonable fashion, given the hardware available.

Reviewer 2:
The project has a clear focus on enabling vehicle-to-grid (V2G) bi-directional flow integrated with solar and distributed resources. The plan is to impact open standards and enable greater use of V2G by focusing on the critical requirements for both on-vehicle and off-vehicle systems, key necessary elements for progress, and the strength of the approach. This project includes taking advantage of the Smart Power Integrated Node (SPIN).

Reviewer 3:
The approach toward achieving the technical goals is adequate. The project has been substantially delayed, and it is critical that important remaining tasks, such as the durability study, are not shortcut.

Reviewer 4:
The project appears well behind schedule and delayed. Some delays are cited on Slide 6 prior to the COVID-19 shutdown. More rigorous project management on timeline delivery would be beneficial.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Open standards work is a valuable outcome which may lead to industry standards. An accompanying technology demonstration is also good to have.

Reviewer 2:
Most of the project tasks have been accomplished; however, there are critical tasks that will require significant time, beyond the expiration date of the project, to be completed.

Reviewer 3:
Overall, the project appears to be making solid progress, though the project team has seen some delays. On-vehicle technology demonstration is completed. For on-vehicle activities, the project team has completed some standards work and a look at grid stability and reliability. Off-vehicle integration is progressing. For off-vehicle efforts, the project team has completed some initial development work and set up for testing. In particular, to date, the project team has focused upon the development of the SPIN system (off-vehicle), both communication architecture and software. Remaining work will focus on verifying open standards. Two activities have been delayed from December 2019 and February 2020, and all testing was halted in March 2020 due to COVID-19. A year ago, their schedule was already noted as aggressive, so this is a source of greater concern. The project team appears to have a plan to do some work in parallel to catch up, and the project has already received an extension.

Reviewer 4:
Delays have put the project behind schedule. COVID-19 does not improve the matter; however, the project inception of 2016 should have yielded further progress than that shown.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project features an excellent collaboration across industry and National Laboratories. Presence of an automotive OEM with significant involvement in the project is a helpful step toward future development of the technology.

Reviewer 2:
The project has brought together a solid team of partners: the Electric Power Research Institute (EPRI) (lead); hardware vendors including a vehicle OEM; two National Laboratories; and the Society of Automotive Engineers (SAE). All appear to be focused on appropriate and key roles and contributing effectively to the project.

Reviewer 3:
Required partnerships with electric utility, EPRI, and auto OEMs are appropriate for this project.

Reviewer 4:
The project team has some very good and capable partners. The presentation did not specifically discuss collaboration and coordination effectiveness; however, delays would suggest it could be improved.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The team has identified a clear path for research remaining under this project, as well as under future efforts. The team has several key elements planned to ensure the fully integrated system is built and tested under the remainder of this project as well as for impacting SAE standards. The project team does expect commercialization to continue through another funded research project.

Reviewer 2:
The future work outlined is an appropriate extension of the project work done so far.

Reviewer 3:
The project was slated to finish June 2020; however, it appears that this is unlikely due to current status and the COVID-19 shutdown.

Reviewer 4:
The remaining challenges are very significant and appear to have been slightly downplayed by the presenter. More clarity should be provided on how the PI will remediate the delays that have occurred during the project and what steps will be taken to ensure that the final tasks will be addressed appropriately.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is focused on enhancing V2G for EVs, including coordination with critical industry standards, which will be needed to move EVs forward in the marketplace. By both improving charging and providing opportunities for load management through EVs as a distributed energy resource, the project supports displacing petroleum.

Reviewer 2:
The project supports DOE VTO goal of EV adoption for energy consumption reduction. EV users could see a customer-facing benefit of having an EV plugged in at home.

Reviewer 3:
In order to investigate energy savings and integration technology, V2G interoperability and benefits need to be defined, integrated, and tested. This concept is addressed in this project.

Reviewer 4:
The project supports the DOE objectives of expanding charging infrastructure for electrified vehicles.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project had sufficient resources and collaborators to achieve the demonstration.

Reviewer 2:
Resources appear to be adequate.

Reviewer 3:
There was no indication made that resources were insufficient. There is a concern that the project will not be completed on time due to delays even before COVID-19 shut down testing, though the PI seems confident the project should be close to completion and within the extension already provided.

Reviewer 4:

The organizations involved in this project have the competence and sufficient resources to complete the remaining milestones. Timing will be an issue, and very likely the project will have to be extended. Will the team members be able to continue the work with the remaining funding?

Presentation Number: elt188
Presentation Title: Bi-Directional Wireless Power Flow for Medium-Duty, Vehicle-to-Grid Connectivity
Principal Investigator: Steven Sokolsky (CALSTART)

Presenter

Omer Onar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

50% of reviewers indicated that the project was relevant to current DOE objectives, 50% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

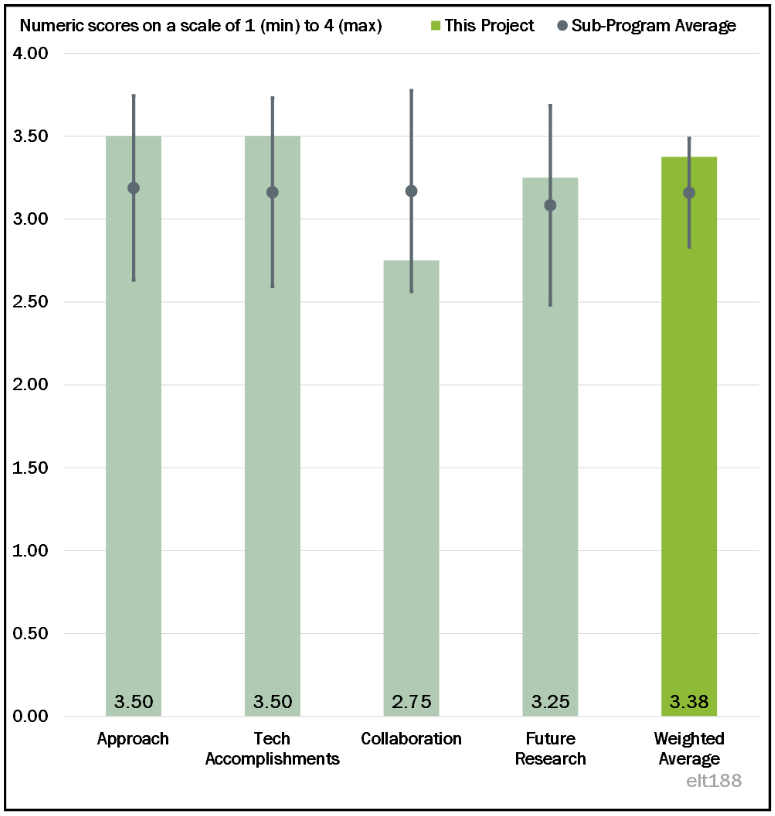

Figure 4-6 - Presentation Number: elt188 Presentation Title: Bi-Directional Wireless Power Flow for Medium-Duty, Vehicle-to-Grid Connectivity Principal Investigator: Steven Sokolsky (CALSTART)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer described the project as an excellent systematic approach.

Reviewer 2:

The project appears to continue to progress toward overcoming barriers outlined and approved previously, using logical framework and partners.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Excellent progress has been made and a lot of hardware demonstrated.

Reviewer 2:

The reviewer had no additional comments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

There is a reasonable level of collaboration.

Reviewer 2:
It would be helpful to have the background and the value proposition from a commercial partner, such as United Parcel Service (UPS), as guidance and metrics for project success.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The future work is consistent with the overall project plan.

Reviewer 2:
The reviewer had no additional comments.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Wireless charging is important for expanding future charging capabilities.

Reviewer 2:
The reviewer did not have the full history of this project or DOE objectives that may be related, so more information from commercial project partners to clarify the value of success compared to the value of alternatives would have been ideal.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources are sufficient.

Reviewer 2:
The reviewer had no comment.

Presentation Number: elt189
Presentation Title: Electric Truck with Range-Extending Engine (ETREE)
Principal Investigator: Jesse Dalton (Cummins-Peterbilt)

Presenter

Jesse Dalton, Cummins

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

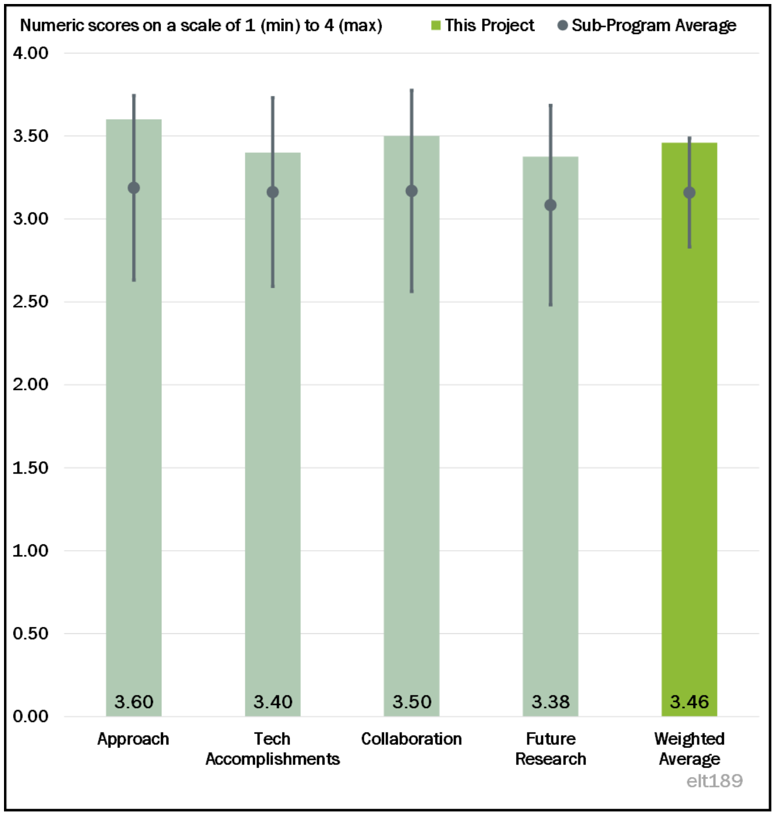

Figure 4-7 - Presentation Number: elt189 Presentation Title: Electric Truck with Range-Extending Engine (ETREE) Principal Investigator: Jesse Dalton (Cummins-Peterbilt)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer was impressed with the approach. There was a good balance of effort, from dealing with changing industry expectations around hybrids (no belief in battery electric vehicles [BEVs] previously to now an almost over-belief or hype in them) to keeping total cost of ownership (TCO) or payback front and center to dealing with component issues, and so on. The reviewer did have a concern with using only the NREL Fleet DNA data. There are too few fleets involved in Fleet DNA. The project made great use though of the 80 and 100 duty cycles since they are representative.

Reviewer 2:

The project approach to understanding customer requirements for Frito-Lay was very wise. Frito-Lay operates class 5-7 pick-up and delivery trucks, comparable performance as conventional and, generally, desire flexibility provided by a range extender. These trucks also have the capability to operate in pure electric mode for a substantial part of route. Frito-Lay was a solid choice.

Reviewer 3:

The fact that the team has managed to get a truck on the road, with a large corporation seriously testing it for possible future use, demonstrates technical feasibility. The economic analysis shows competitiveness under certain conditions, and the PI has suggested improvements to extend the conditions to make it even more competitive.

Reviewer 4:

The project worked as promised.

Reviewer 5:
The project is nearly complete and the key technical goals have been met, which would lead to the conclusion that the approach was well thought out.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The team persevered—good work. The project met the technical goals of zero emission operation and fuel consumption reductions. This reviewer liked using the trip to and from Indiana to Texas for analysis. There are many teams that would have missed this opportunity.

Reviewer 2:
The project accomplishments include a full powertrain demonstrated in test cell. The project team completed two truck builds as well as verification and validation activities for vehicle road worthiness. Additionally, the project demonstrated 65% fuel reduction over the conventional class 6 truck on a modified 80-mile work day duty cycle (NREL80). The project team is conducting on-road testing spanning multiple states and environmental conditions and undergoing a fleet trial with Frito-Lay in Indianapolis.

Reviewer 3:
The addition of a range extender was a key feature. Without it, range anxiety might preclude putting these trucks on actual routes. On the other hand, it is key to keep the additional power supply cost down. In the reviewer's opinion, battery vehicle with small batteries that cover most day-to-day needs, with a small engine backup, is the best of both worlds.

Reviewer 4:
The key vehicle efficiency milestone was met. For vehicle development, the reviewer would rate the project with an "Excellent." An overall rating of "Good" for progress was given due to delay in real-world vehicle testing based on impact of COVID-19. The real-world operation of the vehicle seems like a very critical step in the project and one that seems key to understanding the vehicle performance and the efficacy of the design that resulted from earlier project efforts.

Reviewer 5:
The project is a little behind but that is expected. The project is ending soon.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
A strong team was assembled with industry, academia, and National Laboratories. Cummins, PACCAR, NREL, Argonne National Laboratory (ANL), and Ohio State University (OSU) are all great partners. Frito-Lay is a solid fleet partner.

Reviewer 2:
The project had good coordination with others.

Reviewer 3:
The vehicle developers made good use of the NREL trip data to avoid over-designing the power source. Similarly, operating data will be further used to optimize the size of future range extender units.

Reviewer 4:
The project team reporting of the achievement of key vehicle design specifications would indicate that the team performed well in the area of collaboration and coordination.

Reviewer 5:
The collaboration was strong among key partners. The reviewer perceived a missed opportunity to engage Frito-Lay more. Frito-Lay has much to offer with their detailed understanding of duty cycle data, their experience with all electric box trucks from Smith Electric, and both their interest and concern with BEVs ongoing. This would have been an outstanding place for this team and Frito-Lay to summarize how hybrids might fit in the full spectrum of options. Actually, the reviewer was hoping for such an analysis and slide here in this review.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Future research includes: completing a fleet demonstration trial period with Frito-Lay; investigating use of electric-only operation in certain geographic areas ("geo-fencing") in Frito-Lay's delivery areas; analysis and future research of range extender sizing per class of truck, duty cycles, batteries, and geo-fencing requirements;, continued research on state-of-charge management using fleet management data, traffic, and weather; and continued industry education and outreach on range extender benefits.

Reviewer 2:
Future projects with smaller engines will improve the economics.

Reviewer 3:
The reviewer agrees with the PI's final future research comments on industry education and outreach. The benefits of true BEV medium-duty (MD) trucks will continue to dominate discussions in the trade press and with end-user fleets. Also, the drive to zero emissions, not less emissions, is also dominating consciousness. Hybrids will have a place and the industry needs the knowledge from this work. More explanations should be shared on the total cost of operation compared to both diesel and BEV alternatives. Can this still be done inside the budget of this project?

Reviewer 4:
The project is ending soon.

Reviewer 5:
The COVID-19 impact on vehicle field trials is a concern. The presentation did not make clear if the vehicle will be carried to a commercial platform, leaving the reviewer wondering how did the project impact electrified vehicle availability and viability? The field trial may help answer this question.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Delivery trucks use significant quantities of diesel fuel, creating emissions and noise in cities. Reduction of fossil fuel use is a key DOE objective.

Reviewer 2:
Electrification of delivery vehicles seems promising from an environmental and energy standpoint. Furthering success in this area seems befitting of a DOE project.

Reviewer 3:
Yes, the project is very relevant, addressing cost of the batteries and return of investment (ROI).

Reviewer 4:
The project meets the DOE objectives by proving that large fuel economy improvements can be made while giving fleets the peace of mind to complete their routes without range anxiety.

Reviewer 5:
The project is more relevant now than in prior years.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed a good job completing this work, given challenges along the way.

Reviewer 2:
The reviewer noted good management.

Reviewer 3:
Sufficient resources are allocated to this project.

Reviewer 4:
Based on successful development of the vehicle systems was indicated by this reviewer.

Reviewer 5:
The trucks got built and made it into commercial testing operations.

Presentation Number: elt190
Presentation Title: Medium-Duty Urban Range Extended Connected Powertrain (MURECP)
Principal Investigator: Matthew Thorington (Bosch)

Presenter

Matthew Thorington, Bosch

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

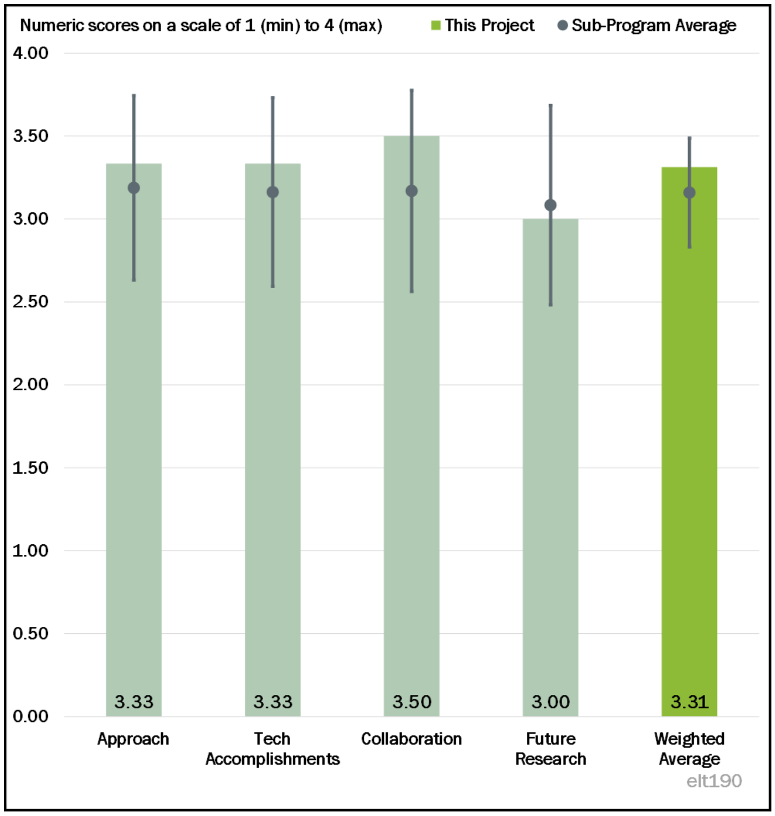

Figure 4-8 - Presentation Number: elt190 Presentation Title: Medium-Duty Urban Range Extended Connected Powertrain (MURECP) Principal Investigator: Matthew Thorington (Bosch)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach was very good, from powertrain development to simulation and then the powertrain integration and demonstration.

Reviewer 2:

It was a good initial thought to reuse existing parts (two motors).

Reviewer 3:

Getting a truck designed, built, and tested is no small feat. However, since the other similar projects also included on-road testing in commercial operation, this project seems like it could have done more. The project seems more into analysis and theory than similar projects. That is not necessarily a bad thing.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

On the chassis dynamometer test, the PowerSplit Plug-in Hybrid Electric Vehicle (PHEV) system consumed 4.3 kilowatt-hours (kWh) of electrical energy, operating 46% of the time in single motor EV mode and 38% of the time in dual motor EV mode. This resulted in a 100% reduction in raw fuel consumed and 58% in diesel equivalent energy consumption (21 miles per gallon equivalent [MPGe]).

Reviewer 2:
Unfortunately, the poster for this project did not include technical details on vehicle and propulsion system architecture, so it is difficult to evaluate how innovative their work was, but the fuel reduction was impressive.

Reviewer 3:
The project team did some testing, but the project is not really different from last year.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Project partners and vendors are a strong team, which include Robert Bosch LLC; University of Michigan; Morgan Olson; VOSS Automotive; Ricardo; NREL; and Freightliner Custom Chassis Corporation.

Reviewer 2:
Getting a new technology design up and running can only be achieved with the collaboration of talented people from many disciplines.

Reviewer 3:
The project had a good partner list.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Future research includes chassis dynamometer testing with fixed transmission temperature sensor and criteria emissions evaluation on the powertrain dynamometer. The project team will also include private test track validation.

Reviewer 2:
Perhaps with more money, the project team could test with a company on the road.

Reviewer 3:
The project scope was cut and is winding down.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project plans to demonstrate 50% fuel consumption reduction utilizing a PHEV powertrain with a dual-planetary gear transmission via deep integration of electric components based on high-volume light duty vehicles.

Reviewer 2:
Anything that reduces our use of liquid fossil fuels is of interest to DOE.

Reviewer 3:
The project indicated decreasing fuel consumption.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
There are sufficient project resources.

Reviewer 2:
This is a tough one, since some of the tasks were not completed. That may have been a COVID-19 problem.

Reviewer 3:
The project was a good try, but it seems like a dead-end for this propulsion architecture in the current form.

Presentation Number: elt191
Presentation Title: Medium-Duty Vehicle Powertrain Electrification and Demonstration
Principal Investigator: Wiley McCoy (McLaren)

Presenter

Wiley McCoy, McLaren

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 25% of reviewers indicated that the resources were sufficient, 75% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

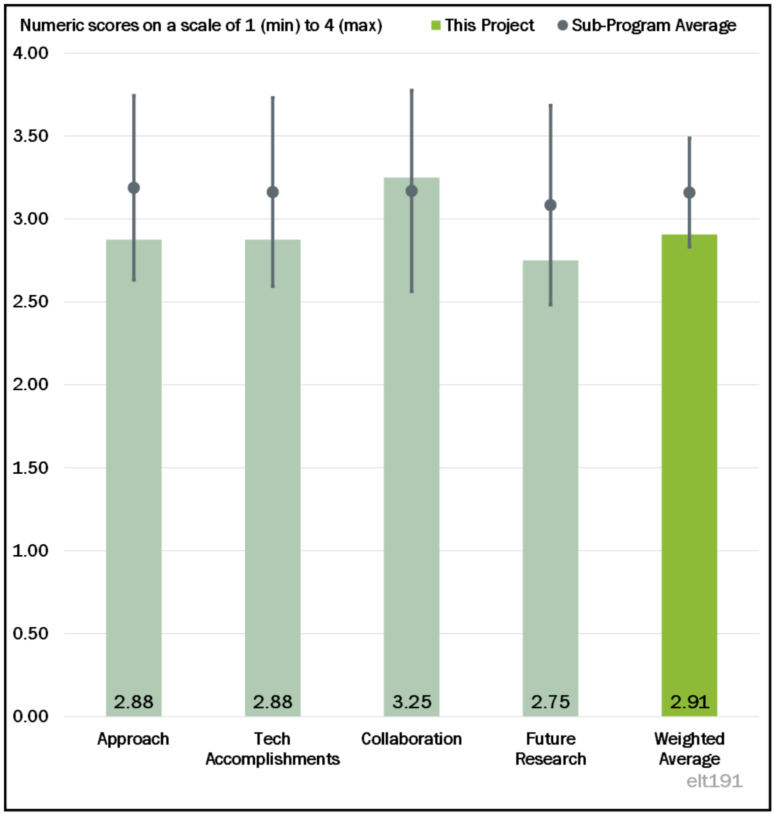

Figure 4-9 - Presentation Number: elt191 Presentation Title: Medium-Duty Vehicle Powertrain Electrification and Demonstration Principal Investigator: Wiley McCoy (McLaren)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer thought the approach of E-motor, E-Axle, range extender, and battery was good. However, based on the results so far, the reviewer would suggest stopping any more work on the first-generation and continue developing or improving a second-generation electric powertrain for MD vehicles for use in the pick-up and delivery arena. Truck electrification has the greatest promise for MD vehicles used for pick-up and delivery, which are needed because such vehicles generally have a high stop-and-go rate and operate in congested areas where emissions are also highest.

Reviewer 2:

The team is very persistent in the face of continuing problems. It is, however, always a hard question whether to give up on a key component that continues to cause problems or to find an alternative and move forward. In this case, delaying replacement of the 2-speed unit caused significant delays. Certainly, much was learned, and something not working is as valid a scientific result as something working.

Reviewer 3:

The project has been impacted by several setbacks and by the shutdown caused by COVID-19. It seems that the timeline has been significantly impacted and DOE funds have been depleted. Since the original objectives will likely not be met, the project lead should focus on re-scoping the remaining objectives and highlight the impact of the work conducted so far.

Reviewer 4:
A number of system failures occurred by what appeared to be a combination of lubrication issues in conjunction with shift control strategies relative to vehicle loading. Although some miles were put on the system in real-world demonstrations, failures ultimately sidelined broader use. However, it appears many lessons in this process were gleaned and are being used moving forward into other potential product streams. This is a positive for potential future technology applications.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The system was designed, developed, and tested in mules. This was favorable. Issues surrounding the design and controls, however, ultimately led to failure.

Reviewer 2:
The project team has made progress toward demonstrating electric trucks. It is really hard to tell how many of the problems were due to a combination of bad luck and trying something really hard, and how many were caused by poor choices.

Reviewer 3:
The project has been impacted by setbacks resulting from multiple breakdowns that occurred during the testing phase. Are there any "lessons learned" from the experience? Additionally, more emphasis should be put toward measuring and benchmarking the performance (fuel economy in particular) of the electrified powertrain.

Reviewer 4:
The reviewer really appreciated the fact that the vehicle had achieved 100% of the DOE's fuel efficiency improvement even though the reviewer was totally dismayed that the PI was not able to tell the audience what the fuel economy goal was or what the fuel economy of the current vehicle was with the improved electric powertrain. It is not clear what the causes of the failure of the remote oil supply/scavenging system, E-motor resolver, inverter, and E-axle shifting were, but the project team needs to be held accountable to explain those causes and assure reviewers that those causes are being addressed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration plan described is very good; the role of the different participants is relevant and well explained.

Reviewer 2:
It is highly commendable and noteworthy that the PI is working directly with an end-user—UPS.

Reviewer 3:
Sufficient collaborators were present to design and test the technology on-road from chassis supplier to technology, and, ultimately, demonstration partners.

Reviewer 4:
Again, so little can be included in such a presentation that it is really hard to know whether any of the issues with this project could have been avoided/ameliorated with better communication among partners. The team seems to have included the right people for the right tasks.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The project needs to continue despite the recent setbacks. There is very high potential for this project to succeed, very high need for it, and it is very clear that the end-user supports it.

Reviewer 2:
In spite of setbacks, the team has a plan to actually get the job done, and the team should be commended for that.

Reviewer 3:
The project is completed relative to the funding and project timing. However, although targets were not met, it was stated that what was learned from the failures will be applied to future works.

Reviewer 4:
Given that the project is approaching completion, any effort should be directed toward demonstration and verification of benefits.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project aims at demonstrating a plug-in hybrid powertrain for MD delivery trucks and quantifying performance (fuel economy improvement), cost, and reliability.

Reviewer 2:
Delivery trucks use lots of fuel and pollute inner cities; successful completion of this project will help reduce both problems.

Reviewer 3:
Yes. DOE core objectives include energy efficiency and reducing reliance upon non-renewable energy sources. Technical research projects into transportation sectors currently not utilizing electrification are a key ingredient to these objectives.

Reviewer 4:
This reviewer indicated the same answer as prior comments.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer strongly suggested, even urged, adding more funds as necessary and appropriate to allow the project to continue if the project is in danger of being underfunded.

Reviewer 2:
Given the challenges and setbacks that occurred during the project, significantly more resources should be allocated before the concept is translated into a product that can be commercialized.

Reviewer 3:
The team does plan to deliver the promised product, in spite of having trodden a bumpy road.

Reviewer 4:

The project is nearly completed without success, and additional funds were spent by the contractor to get to the final result.

Presentation Number: elt197
Presentation Title: High Power and Dynamic Wireless Charging of Electric Vehicles
Principal Investigator: Veda Galigekere (Oak Ridge National Laboratory)

Presenter

Veda Galigekere, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

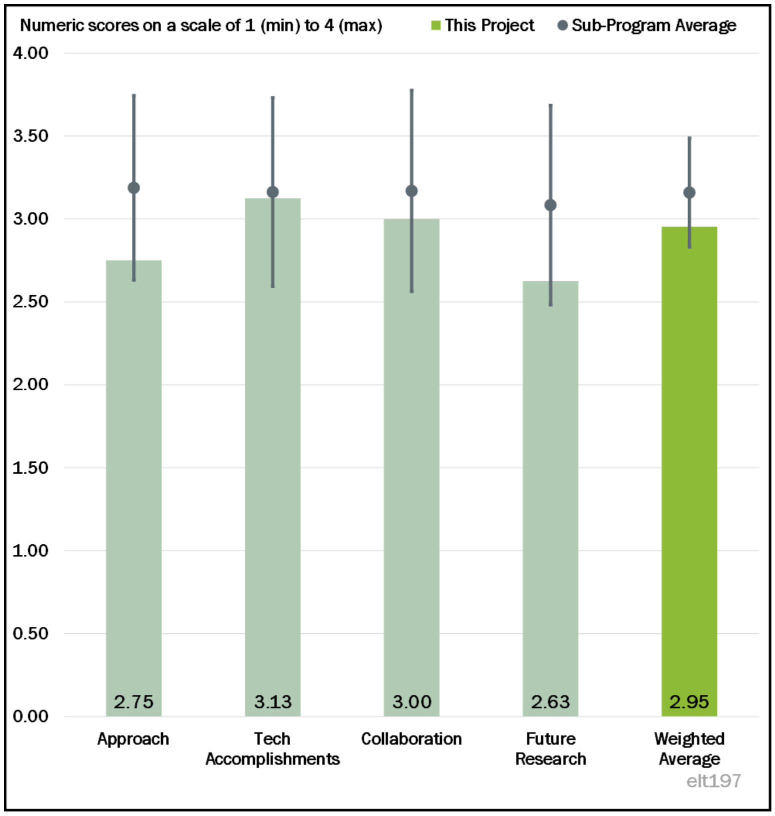

Figure 4-10 - Presentation Number: elt197 Presentation Title: High Power and Dynamic Wireless Charging of Electric Vehicles Principal Investigator: Veda Galigekere (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Going step-by-step is a very good way for the approach, and this project is doing that. The project culminates with a vehicle-level validation.

Reviewer 2:

The approach looks solid. It starts with targets, then laboratory-scale testing followed by real-world validation test. The project has demonstrated some success with the completion of the go/no-go milestone in September of 2019. The timeline on Slide 9 seems to be incorrectly marked as 2018 and 2019 rather than 2019 and 2020.

Reviewer 3:

There is a good approach, but some intermediate verification of the dynamic aspect would be helpful.

Reviewer 4:

The reviewer’s comments hinged on the feasibility portion of this project and the lack of information (apparently) captured about cost, ownership, responsibility, funding, maintenance, automaker standardization, and others compared to present alternatives that leverage larger batteries with non-roadway fast charging locations, especially considering likely continuation of improvements in both battery density and cost.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project has accomplished a significant amount of technology. The simulation has been good as well as the hardware development.

Reviewer 2:
This may not be fair if the project team did not have control and/or input into the project objectives and barriers to overcome, but it does not seem that this project is adequately determining whether this approach can meet consumer expectations and needs with a value proposition that exceeds that of others currently in place for corridor fast charging.

Reviewer 3:
A lot of progress appears to have been made over the past year with 4 accomplishments from FY 2019 mentioned and 15 from FY 2020. There was no mention of impact on the schedule due to COVID-19 related closures. While it is understandable that many of the analysis tasks could have been completed remotely, the reviewer suspected there will be delays for the go/no-go decision point associated with the standalone test of 200 kilowatt (kW) power electronics and completing the overall FY 2020 phase of validating a 200 kW Dynamic Wireless Power Transfer (DWPT) systems in the laboratory.

Reviewer 4:
Good progress has been made but since most of the milestones are still in progress, it is hard to reach an accurate assessment at this point. More details about the dynamic aspect of charging should be included

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer found good collaboration among participating organizations.

Reviewer 2:
Collaboration was comprised of three laboratories and three outside entities. Each team member had a clear and complementary scope.

Reviewer 3:
The teams seem to be gainfully working toward the same goals in a coordinated fashion.

Reviewer 4:
A key missing perspective here is that of consumers and federal and state agencies that would be integral partners for any deployment and maintenance of such assets.

According to the reviewer, there are key missing answers to these questions: Would this deployment materially affect EV adoption independent of other factors? Are deployments along federal and state transportation corridors physically, technically, and legally feasible? Who would need to fund this equipment and the accompanying installation and deployment, and what is the feasibility of such an investment?

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
More focus on the dynamic aspects is needed.

Reviewer 2:
The future research looks appropriate and logical. It would be good to hear more about the work needed on the pavement side of the system and the implications (both technical and cost) to the roadways when that information is ready to be presented.

Reviewer 3:
Using a single active rectifier on the secondary side is a very good way to minimize the complexity. Has any thought been given to the reliability of the system and the backup for that reliability? Near future needs will need much higher power levels. The 200-kW level is high good for initial development and good for passenger vehicles. However, soon commercial trucks will need higher power to keep them moving, assuming this is a good solution. Any initial roadway developments should include higher power levels and just not be limited to passenger vehicles.

Reviewer 4:
The project seems to have continued beyond the feasibility portion without sufficient justification.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project supports DOE's overall objectives. If successful, it will provide cleaner, more efficient transportation options.

Reviewer 2:
Dynamic wireless power transfer is very relevant for the future of charging.

Reviewer 3:
This project is relevant. It needs to make sure that tearing up a roadway to install this technique is relevant for the future. In general, it seems as though it will be very expensive and cause significant maintenance for the road system. How much of the road system needs to be torn up? Do you put a half mile down every 10 miles? What is the duty cycle?

Reviewer 4:
Considering and vetting alternatives that enable long distance electric travel for consumers is important, and the reviewer believed that the project does support DOE objectives, but more attention is required on feasibility and value propositions.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
It appears to the reviewer that resources are sufficient.

Reviewer 2:
The resources seem to be sufficient for the work that needs to be completed.

Reviewer 3:
Great accomplishments with the given resource.

Reviewer 4:
The reviewer provided no comment.

Presentation Number: elt198
Presentation Title: Cybersecurity: Securing Vehicle Charging Infrastructure
Principal Investigator: Jay Johnson (Sandia National Laboratories)

Presenter

Jay Johnson, Sandia National Laboratories

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 86% of reviewers indicated that the resources were sufficient, 14% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

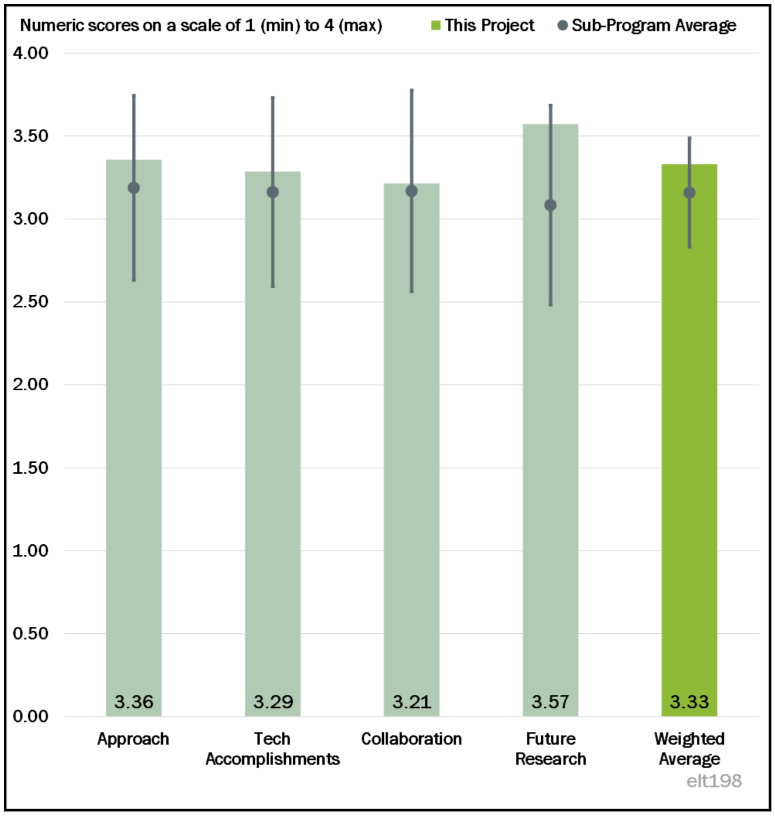

Figure 4-11 - Presentation Number: elt198 Presentation Title: Cybersecurity: Securing Vehicle Charging Infrastructure Principal Investigator: Jay Johnson (Sandia National Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

By building models to quantify cybersecurity risks to electric vehicle supply equipment (EVSE) and establish actionable recommendations to protect charging infrastructure, automotive, charging, and utility stakeholders can better protect customers, vehicles, and power systems in the face of new threats. The project team approach is solid.

Reviewer 2:

The approach appears to be developed in a rational and detailed manner, with each element of the approach addressing the key issues. This is a complex area to address, and this project is only at the front end of research. It is also good to see that the project is designed to address security concerns covering multiple areas (not just technical, but also business, etc.) as well as various sources of attacks.

Reviewer 3:

This project represents a timely, first, fully comprehensive threat assessment looking at the entire EV and EV charging and grid ecosystem. It provides a high-level view of the risk landscape, interconnected assets, secure and unsecured interfaces, and attack surfaces. The project takes a two-pronged approach: (1) vulnerability assessment and threat model development and (2) investigation of consequences associated with charging/vehicle vulnerabilities with regard to the grid. The end goal is to create a risk-based matrix and prioritize mitigation strategies. The approach is very logical and clearly recognizes it is impossible to guard against all potential cyber-physical attacks and as such a substantiated and robust prioritization process is essential.

The presentation provides a clear objective and stated project milestones to provide timely and useful information for stakeholders to improve cybersecurity across the EV and EV charging and grid ecosystem, including OEMs, EVSE vendors, network operators and aggregators, utilities, and standards developing organizations (SDOs).

Overall, no specific weaknesses are noted in the project approach. The project approach is very well designed, logical, and directly addresses the technical barriers. This includes the reality that the EV and EV charging and grid ecosystem is a complicated system of systems which includes numerous stakeholder entities and interfaces, all of which pose potential cybersecurity risks. The project identifies a number of technical barriers and gaps, including the lack of a comprehensive cybersecurity approach, limited best practices, and incomplete industry understanding of attack surfaces, interconnected assets and unsecured interfaces. The project specifically addresses these barriers. On Slide 7 (EV Charging Attack Graphs), the presentation identifies the use cases for which the attack graphs were created. It would have been helpful to identify the logic and process used to determine the specific use cases to pursue.

Reviewer 4:
The use of spoofing, tampering, repudiation, information disclosure, denial of service, elevation of privilege (STRIDE) is an appropriate means of getting your hands around a difficult problem if one assumes no system is invulnerable. The approach helps to identify the wide spectrum of potential risks in a systematic way.

Reviewer 5:
Applying a threat model toward alternating current (AC) and direct current (DC) charging stations and then evaluating consequences and grid impacts are an excellent approach. This uses existing standards and then applies different teams to determine threat and vulnerability levels. This established a basis for the industry to evaluate their product and improve it along with providing updates to the standards.

Reviewer 6:
On Slide 11 it is difficult to quantify probability. How can the probability be related to accessibility of the attacker to insert vulnerability into the system? On Slide 18 under Demos and Experiments, these should be considered to be essential rather than optional to support a recommend solution.

Reviewer 7:
The reviewer observed a good start although some changes should be made. However, this can still be an excellent project and contribute real value. In terms of strengths of the approach, simply focusing on this problem is excellent; this is a difficult and consequential issue. Using an adversarial mindset and including partners (e.g., National Motor Freight Traffic Association, Inc. [NMFTA], which well understands a segment of industry and can provide their perspective and vision) to develop the threat model is excellent. Using attack graphs is excellent.

There are opportunities for improvement. The reviewer had two specific items which, if accepted, would strengthen the project team's work product. The first is to embrace crypto-agility and work it into the project's guidance and solution—the project can use public key infrastructure (PKI) guidance as a specific exemplar, but make sure the project team does not force a solution which might be irreparably compromised within the expected lifespan of the fielded equipment which are using your guidance during the design and development activities. The second is to accept the simple fact that the major enemy is a nation-state adversary—do not hand-wave away this likelihood (as currently done in the project risk matrix). It was en vogue in the 2000-2008 timeframe to hand-wave away the risk from a nation-state actor, but reports suggest that by 2018 over a quarter of all cyberattacks were state-actor backed. This completely changes the approach, concerns, and the threat matrix. It also makes the project research both valid and allows it to protect real-world systems, given the changing reality of the adversary. Similarly, please also consider organized crime strongly in the project risk matrix and the resources organized crime would bring to the hacks.

Regarding concerns, the project highlights PKI and has a specific milestone (FY 2021) tied to PKI. The problem with this is that Quantum Crypto is getting very much closer to being a serious threat and if the project does not have crypto-agility built into its recommendations and the solution set and if the project does not allow for crypto-replacement, the project will likely strand products developed under its recommendations.

The reviewer found two major weaknesses that should be corrected. The first is the appearance of a reliance on STRIDE; the reviewer believed this is a fault—not even Microsoft exclusively uses STRIDE and there are ample studies to suggest a hybrid approach (see Software Engineering Institute research) using things, such as Common Vulnerability Scoring System or Security Cards, and then applying STRIDE to the pruned results delivers much better results. While STRIDE minimizes false positives, the reviewer thought the real concern was false negatives and it is certainly less than clear that STRIDE is a good tool for that. STRIDE is excellent for inexperienced teams and provides a checklist approach, but the reviewer emphasized that the project really needs a significantly better system for something as important as design of product that will live for decades in the infrastructure.

The second major weakness is that the project has not brought in outside reviewers. For reference, the Department of Defense brings in commercial red teams to attach highly classified systems and help with design approaches. The project should rotate between companies so no one company performs more than one assessment. The project team is accepting real risk and, in the reviewer's opinion, probably compromising the overall value by not availing itself of outside parties

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
There is excellent progress on identifying EVSE vulnerabilities and risk mitigation via red teamwork.

Reviewer 2:
This provides an excellent basis that will lead to next steps in this ongoing effort. The need to continue to improve, adjust, and understand new approaches is ongoing as the standards continue to be updated with more features and as more products come to market.

Reviewer 3:
The project has already begun to identify vulnerabilities in systems and standards, which will be critical for improvements to occur. The team has seemed to learn a great deal since the beginning of the project, and this learning will clearly expand the knowledge in this area. The accomplishments appear to be a clear result of the project design. The detailed Vulnerability/Consequence matrix is an interesting documentation approach.

Reviewer 4:
The project identifies a cascading sequence of activities, including red team testing of EVSE, identification of EV charging components and information flows, a comprehensive threat model, attack graphs, impact analyses with regard to grid distribution and transmission systems and impacts, and ultimately a comprehensive risk matrix and prioritization of mitigation actions.

In the last year, the project has made notable progress, including further development of the threat model, EV charging attack graphs, red team assessments of several chargers and International Standards Organization 15118-2 PKI requirements, and an update on power system consequences, including the potential for interarea forced-oscillations. A particularly notable element is that the project will have actionable results by the end of FY 2020, including attack graphs and hardening recommendations that will be useful to industry in the near term.

The threat modeling model of EV charging identified some findings, including that the energy sector cannot mitigate every extreme fast charging (XFC) threat on their own and that all XFC parties need strong coordinated cyber practices. This begs the question: what are recommended as the best methodologies to coordinate future cyber practices across the EV and EV charging and grid ecosystem?

Reviewer 5:
The team created attack graphs for the following use cases: Outsider to Business Network Presence, Deployment of Malicious Firmware, Physical Compromise of EVSE, and EVSE to Vehicle. The team has these models active and has discovered some weak points with this.

Reviewer 6:
On Slide 10 limited information was provided regarding actual results. The project team should consider alternative solutions to sharing the claimed sensitive results.

Reviewer 7:
The reviewer commented that excellent progress against meaningful goals as a strength. However, opportunities for improvement include the two weaknesses noted previously as well as the two improvement opportunities noted as part of the project team's goals list. This reviewer also stated concerns and weaknesses.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This has an outstanding collaboration across project teams from the National Laboratories, government, and industry partners along with the list of external collaborators. This mix of effort provides the balance needed to meet the goals of this project.

Reviewer 2:
Collaboration appears to be very good, with a really strong team of participants all with clear roles. The PI indicated that the list of partners has grown during the project. The team has been reaching out to the EVSE vendor community about the project and since the project team is having success at identifying threats, that has been useful in bringing new members onto the team. The project team is also coordinating with the other VTO cybersecurity project teams, as well as a number of federal offices and industry partners.

Reviewer 3:
The project maintains a strong and diverse team of Sandia National Laboratories (SNL), Pacific Northwest National Laboratory (PNNL), ANL, the U.S. (United States) Department of Transportation (DOT) Volpe Center, NMFTA, multiple DC fast charging (DCFC) vendors, and a large utility. It also identifies a number of external collaborations with DOE VTO-funded cybersecurity projects and government agencies. It would have been beneficial if the roles of Volpe and NMFTA were more clearly explained.

Reviewer 4:
On Slide 2 the presenter indicates two DCFC vendors (or multiple on Slide 13) and one utility not indicating their specific role and the expertise these partners bring to the project. The presenter did indicate the specific role of each identified supporting laboratory very well on Slide 12.

Reviewer 5:
There is a wide spectrum of partners, which is good. Idaho National Laboratory (INL) seems to be doing work on EVSE cybersecurity projects but the reviewer did not see them listed.

Reviewer 6:
The collaboration team is well assembled. However, as mentioned previously, the red team appears to be all National Laboratory employees. The project may benefit from using consultants with specialized expertise.

Reviewer 7:
The reviewer stated that one strength of the project is that highlighting different roles for the National Laboratories provided good insight. As for opportunities for improvement, the reviewer recommended providing more transparency for team coordination and work roles for future Annual Merit Reviews (AMRs). Given that NMFTA (specifically) would be able to present an excellent set of business concerns and priorities, their role should be highlighted as part of the threat description phase (especially if the project uses prior comments about stepping away from an exclusive use of STRIDE and begins a hybrid approach or some other better-than-check-boxes methodology).

The briefing included an excellent slide describing the different roles for each of the participating National Laboratories, but there was no chart describing roles for each team member nor was there much indication of how work was broken down among team members.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Future work includes developing standardized policies for managing chargers and other assets in the charging ecosystem and designing effective perimeter defenses to protect the assets, such as firewalls, access control lists, and dat*a-inflight requirements (encryption, node authentication). This is solid future research.*

Reviewer 2:
The reviewer stated that a strength of this project is the excellent insight into needed next steps and future research projects and initiatives needed to secure this portion of the industry. Particularly, focusing on human understanding and practice will be very helpful. The reviewer suggested considering the addition of layers of defense beyond perimeter security as a future objective. Concerns and weaknesses were also stated by this reviewer.

Reviewer 3:
On Slide 14 the presenter identified well the specific contribution in the overall ecosystem of contributions.

Reviewer 4:
The project team has a clear plan for the remaining research required. There have been some delays due to COVID-19, but the delays do not appear to be significant so far.

Reviewer 5:
Next steps are appropriate.

Reviewer 6:
This is an ongoing effort and will continue to expand as new products and suppliers enter the market with variations on how these players implement security requirements. As vehicle charging and additional services continue to grow and expand, this effort needs to expand to match these needs.

Reviewer 7:
The project has clearly and logically laid out its future work as evidenced by a comprehensive and sequenced milestone listing. This includes publishing attack graphs and hardening recommendations (FY 2020), completing a draft threat model (FY 2021), completing the consequence study mapping EV and charging vulnerabilities to power system and infrastructure impact (FY 2021), providing a hardening guide for EVSE vendors (FY 2021), and completing PKI recommendations for SDOs (FY 2021). There is really no discussion of appropriate decision points nor discussion of mitigating risk by providing alternate development pathways.

However, given the relatively limited time available to present (20 minutes), it is understandable these areas really were not covered.

On Slide 14, the presentation provides a strong listing of remaining challenges and barriers, and additional work that should be targeted. This includes standardized policies, designing perimeter defenses, creating situational awareness and detection and prevention systems, researching response mechanisms, and creating contingency operating modes. It would be good to provide some thoughts on the next systematic steps to further the comprehensive approach to cybersecurity. For example, would it be beneficial to first set up a consortium and, if so, who would it include? The presentation mentions that the project team is reaching out to some industrial entities, such as OEMs, to better understand the real-world implementations of telematics systems for the threat models. But, more broadly, it would be good to know the overall plan for review of project results from the industrial and commercial perspective. Last year, a reviewer indicated it would be good to include a commercial cybersecurity firm(s), but SNL had indicated the sensitive nature of the red team assessments does not permit this. The reviewer wondered if somewhere in the overall review process (such as for the threat model and attack graphs) is there not potentially a beneficial role for a commercial cybersecurity firm which would not compromise the project's sensitivity?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project supports EV adoption by looking at ways to protect EV charging infrastructure. This is important to DOE VTO objective of wider EV adoption, which in turn reduces vehicle energy consumption.

Reviewer 2:
The project is focused on cybersecurity for EV charging, which will be a critical area of development to enable a move toward electrification, thus displacing petroleum.

Reviewer 3:
To quantify cybersecurity risks to EVSE and establish actionable recommendations to protect charging infrastructure allows automotive, charging, and utility stakeholders to better protect customers, vehicles, and power systems in the face of new threats. This is necessary to move electric vehicles into the U.S. market.

Reviewer 4:
This project is highly relevant. As the number of EVs and associated communications networks for EVs, EVSE, and external systems increase, attack vectors and cyber risks also increase for the charging infrastructure and the electric grid. This project represents the first truly comprehensive effort to understand the risk environment and provide a ground-up threat assessment for the EV/EVSE/grid ecosystem. It will provide the foundation to further a systematic approach to cybersecurity.

Reviewer 5:
The numerous actors and product will continue to expand, and providing a secure interface and response needs to match growth in electrification. By establishing a threat model and providing suggested approaches for cyber resilience, the grid, charging equipment, and vehicles have a better model to use in implementing security systems.

Reviewer 6:
The project identifies EV charging infrastructure cybersecurity risks.

Reviewer 7:
The reviewer found the task focus to be exactly aligned with critical DOE interests and concerns—security of both grid and the non-grid side of the vehicle charging problem are crucial for societal adoption and then for societal protection. There are opportunities for improvement and being even more relevant if the project team makes sure to respond to earlier comments. These will ensure crypto plan, red team results, and guidance

documents are the things that can provide protection to the infrastructure over at least 1.5 times the expected life of the charging stations. For example, if PKI will fail due to quantum crypto in 20 years and if the charging station has an expected life of 30 years or less, then a plan for crypto-agility is needed or the implemented project results are simply causing a massive vulnerability at the 20-year horizon—and that is obviously bad.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources appear sufficient at this time.

Reviewer 2:
The resources ($3 million) are sufficient for the proposed task and deliverables.

Reviewer 3:
The work is on time with the provided resources.

Reviewer 4:
The resources are sufficient, but this is a small sampling of the product for AC and DC charging. More will be needed to expand to other products and functions for connectivity.

Reviewer 5:
There are very little data regarding resources other than money, which makes it impossible to conduct a meaningful estimate/evaluation of sufficiency, so the reviewer may have erred with the assumption that usage and availability were outstanding. The reviewer suggested to the PI, for future AMR sessions, to please provide equipment lists (including software) and also spend rates versus estimated spend rates so the reviewer can understand progress against schedule and cost goals as well as “tool” sufficiency.

Reviewer 6:
The utility and EVSE suppliers’ resources and contribution to project are not clear.

Reviewer 7:
The red team needs to be improved.

Presentation Number: elt199
Presentation Title: Cybersecurity: Consequence-Driven Cybersecurity for High-Power Charging Infrastructure
Principal Investigator: Richard Carlson (Idaho National Laboratory)

Presenter

Richard Carlson, Idaho National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

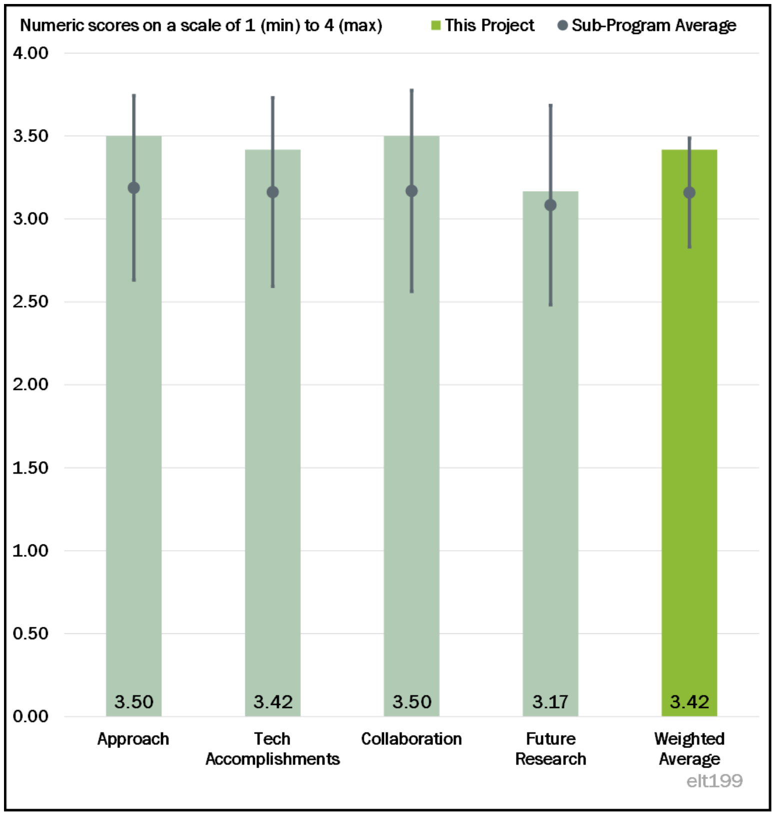

Figure 4-12 - Presentation Number: elt199 Presentation Title: Cybersecurity: Consequence-Driven Cybersecurity for High-Power Charging Infrastructure Principal Investigator: Richard Carlson (Idaho National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach is well thought out and executed to meet this critical need for high powered systems. These are complex systems that must interface with more stakeholders than simple Levels 1 and 2 residential vehicle chargers. The broad-based interactions are being studied to assess high consequence events (HCEs). Included are conductive and/or wireless chargers and installations with many chargers on a site. The project is not covering grid "before-the-meter," only after. That would be another project that eventually should be coordinated to this one. Not covering just hardware threats but working to identify HCEs that must be mitigated on a complex system, then developing mitigation strategies. This is a very comprehensive system engineering approach.

Reviewer 2:

A strength of this project is its clear, logical, and obviously relevant approach, which makes understanding this research and assessing both its progress and its relevance straightforward. The reviewer also found the Impact Severity Scoring to be clear, thoughtful, and relevant; indeed, it is one of the best scoring frameworks the reviewer had seen.

While this is not an actual recommendation, it is a request to consider something. It appears that the Impact Severity Scoring has equal weights across rows and columns, but is this sound? Perhaps the project could consider a sliding scale along the severity index, and perhaps even some of the rows are more consequential than others. The reviewer understood this adds complexity and, after reflection, might be valueless. However, the reviewer suggested to consider it and see if (for example) effect propagation should not be weighted a bit more strongly than duration.

Reviewer 3:
The approach includes high power charger providers and adds a ChargePoint operator for additional aspects. Leveraging other DOE projects and universities is also an excellent use of resources to complete the objectives of this project.

Reviewer 4:
The project appears to be clearly designed to address potential threats to the EV charging system. This includes a clear focus on the HCEs that can occur from a number of system vulnerability sources. The design specifically relies upon evaluation of both impact severity and complexity in order to develop more complete approaches to solutions.

Reviewer 5:
So far, the project seems to be moving in the right direction while approaching the testing of various ways to violate cybersecurity when it comes to charging.

Reviewer 6:
Based on the provided Gantt chart, it seems that there are some challenging issues with preparing laboratory equipment and laboratory evaluation. Some tasks are a bit overdue with no explicit justifications.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The milestone-based report clearly states the path and the progress. The project has developed a scoring system that can be reused on many new systems. The project team will be evaluating strategies and solutions in laboratory environments that should take the end product of this project to a technology readiness level (TRL) of 5-6 by project end. The assessment follows a logical path to create positive outcomes. Detailed technical evaluations (i.e., thermal spoof and the multi-charger sudden stop) are excellently presented.

Reviewer 2:
The reviewer noted that there are excellent results, which are clearly presented and make sense. On the other hand, the PI needs to show (or convincingly argue) there is equivalency between a Raspberry Pi (reference Slide 10) and the objective hardware and software combination running on the actual EVSEs.

The reviewer's concerns were more of a request for clarification. Item 5 on Slide 7 is "feeder equipment damage," but it is listed under Grid Impacts rather than Hardware Damage. Is this just a typo (in which case the reviewer understood) or is there a nuance associated with hardware damage which the reviewer was missing? If there is—the reviewer was really missing it—so, please offer a bullet or sentence in the published materials explaining that nuance so everyone can understand the results.

Reviewer 3:
The project appears to be making progress largely in accordance with the plan. A large number of HCEs have been identified, with particular emphasis on grid impacts and safety, which is good to see. The next level of impact does indeed include impacts on EVs themselves. While perhaps a lower chance for occurrence, a significant impact on the confidence level of EV purchasers is possible.

Reviewer 4:
Because this project is 50% complete, it has the basis for positive results, but more time is needed to properly access how the ongoing evaluations lead to solutions.

Reviewer 5:
The reviewer was not sure that the project team has covered all of the possibilities. The project team seems to put a lot of emphasis on a direct entry point by actual contact and less on introducing a deviant over-the-air or transmitted through a communication apparatus.

Reviewer 6:
Based on the provided Gantt chart, it seems that there are some challenging issues with preparing laboratory equipment and laboratory evaluation. Some tasks are a bit overdue with no explicit justifications.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
All of the players are dispatched in what they excel. The project team members have experience in what they are dispatched to do.

Reviewer 2:
The partners and collaborators included have the background and experience to lead to positive results. This project varies from others as it focuses consequences, impact severity, and safety aspects.

Reviewer 3:
The team seems to have a good set of both laboratory and industry partners. Additional collaboration has occurred with DOT Volpe and the 21st Century Truck Partnership, as well as WAVE Inc., Utah State University, and the other VTO cybersecurity projects.

Reviewer 4:
It is great that collaborations are broad based and continue to expand. It was not clear whether there were new collaborations required to complete the project or if this group is sufficient. Expansion would be an excellent move.

Reviewer 5:
The project shows strong performers focusing on areas of their strength.

It would be helpful if the presenter showed how the team worked with and interacted with the other four DOE projects mentioned on Slide 14. It is not clear what the input paths are and how cross-task information is being used to accelerate or validate the project's work. Also, it would be helpful if the presenter provided a bit more detail about the different collaborators and how each was working on the different tasks (which the presenter did a great job of showing in the schedule slide).

Reviewer 6:
Collaboration is among National Laboratories (INL, NREL, ORNL), charger equipment manufacturers (Tritium, ABB), charge site owner-operator (Electrify America), and some additional EV charging infrastructure cybersecurity collaboration. Although the collaboration has been mentioned in general, the level of engagement, involvement, collaboration, or technical feedback of some mentioned collaborators is not clear.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Future research is very well based on the accomplishments to date and follows the path that was originally defined for the project. It is good to see a project that has not had big hiccups! The approach is well thought out to meet this critical need for high powered systems. These are complex systems. The project is not

covering just hardware threats but working to identify HCEs that must be mitigated on a complex system, then developing mitigation strategies. Excellent work.

Reviewer 2:
The project has a detailed plan for future research for the remainder of the schedule, including extensive publication of results. There was no indication of any plans for any follow-on research after this project.

Reviewer 3:
As a strength, the reviewer said that the next steps are logical, completely reasonable, and comprehensive. The project team could describe if future study targets will be intended for production or actual "to be fielded" units and describe the benefits and drawbacks in each case. The presenter could show what the value is to both infrastructure and manufacturer if work is done with pre-fielded products and can influence final build products.

Reviewer 4:
Future work is expected to include laboratory evaluation to validate equipment capabilities. It is expected that this will lead to adjustments in security approaches to improve aspects and provide suggestions for updates needed for the industry in existing and future product.

Reviewer 5:
The reviewer believed the project team will have difficulty accounting for the grid through laboratory work. The reviewer also thought it would be hard to duplicate as not all grids are created equal across the country when it comes to resilience and a reaction to a cyber-attack.

Reviewer 6:
The future research has not been clearly mentioned. Also, since more than half of the time of project has passed, the main part of the project in preparing laboratory equipment and laboratory evaluation has not been completed. Furthermore, the barriers and solutions to the challenges have not been discussed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The objectives outlined here match well with the priorities of DOE and real issues to be addressed.

Reviewer 2:
The focus of the project is cybersecurity for EV charging, a critical area to address for a transition to EVs to be successful.

Reviewer 3:
As a strength, the project posed critical questions and offered solutions to an emergent and necessary DOE focus area. This reviewer also stated opportunities to improve, concerns, and weaknesses.

Reviewer 4:
The cybersecurity of the complex charging network is a critical enabler of the adoption of high powered EVs. The methodology developed is intended to be published for use by system developers for future use. It would be most relevant if the development would be continued and this process became a standard in partnership with the system developers and user groups.

Reviewer 5:
Results from this ranking and scoring of HCEs will help the industry and focus the effort into proper categories of impact severity and cyber manipulation. Generally, targets are focused on higher impact areas; however, even lower levels still need attention. Laboratory results will provide continuous improvement in security approaches.

Reviewer 6:
The review was on the fence with this experiment as the VTO deals with vehicle technology and not necessarily the infrastructure charging the vehicle. This deals more with the broad spectrum but does not bring it back to the vehicle in the real sense.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources appear sufficient at this time, though the reviewer would anticipate follow-on efforts in this area.

Reviewer 2:
The maintenance of progress according to plan indicates that the resources are adequate and appropriate to complete the project.

Reviewer 3:
Everything seemed fine to the reviewer. There are no indications there were problems with resources or milestones. The reviewer particularly liked the presenter's openness about the schedule and where the project was on the list of tasks and subtasks. The reviewer also noted opportunities to improve, concerns, and weaknesses.

Reviewer 4:
The reviewer believed the project team has what is needed to finish this project.

Reviewer 5:
The provided resources seem to be sufficient to support the execution of the project.

Reviewer 6:
Collaboration with other laboratories, equipment manufacturers, and charge point providers provides a good balance of focus on the goals of this project and is expected to lead to positive results.

Presentation Number: elt200
Presentation Title: Scalable Electric Vehicle Smart Charging Using Collaborative Autonomy
Principal Investigator: Steve Chapin (Lawrence Livermore National Laboratory)

Presenter

Steve Chapin, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

75% of reviewers indicated that the project was relevant to current DOE objectives, 25% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 25% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

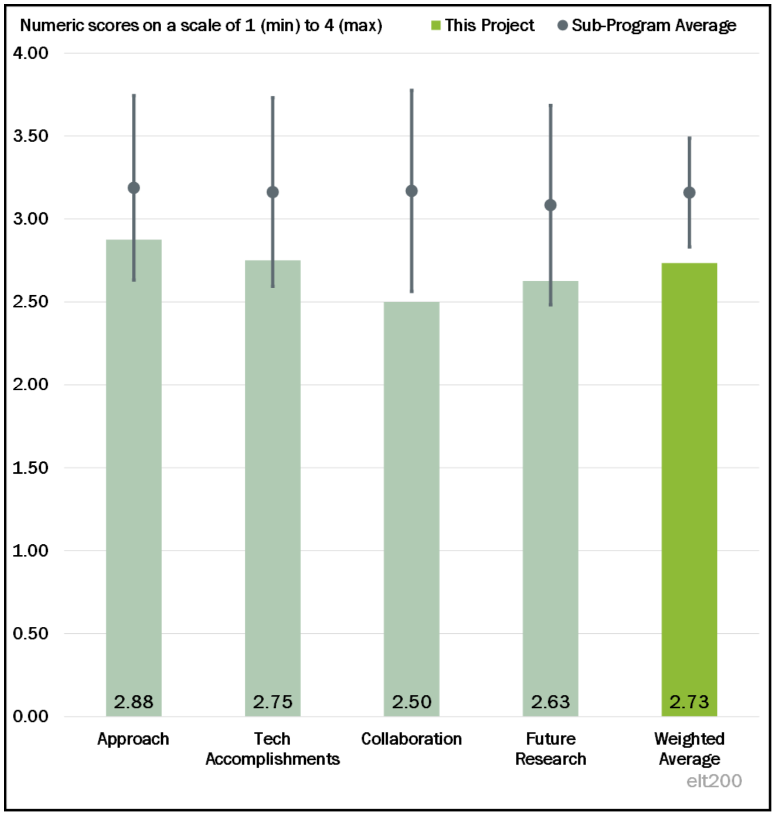

Figure 4-13 - Presentation Number: elt200 Presentation Title: Scalable Electric Vehicle Smart Charging Using Collaborative Autonomy Principal Investigator: Steve Chapin (Lawrence Livermore National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The approaches look effective at this point. It should be able to overcome the barriers.

Reviewer 2:
This approach is viewing the generation variations to load variations. It appears the solution to increased demand from more EVs is to add spinning reserves instead of managing or planning EV charging needs with existing capacity. It also appears that partnering with ChargePoint has not been successful in sharing data for this project.

Reviewer 3:
This project has taken an appropriate approach by combining optimization modeling, distributed computing platform development, and hardware-in-the-loop and coupled simulations using the Hierarchical Engine for Large-scale Infrastructure Co-Simulation (HELICS) co-simulation platform and high performance computing (HPC) to develop, validate, and demonstrate decentralized algorithms for EV charge management.

Reviewer 4:
The reviewer had the following comments:

- The project goals and objectives are ill defined. The objective slide says, "to develop an algorithm," but that does not explain for what the algorithm is going to be used.

- What is so important about developing this algorithm? Will not having it make any significant difference to society, energy security, fossil fuel consumption, or climate change? Who is the end-user of the algorithm?
- The assumptions of both the model and the modeling scenarios are not well laid out and not clear. Whether the model and its results are realistic usually are predicated on the assumptions that go into the model. How realistic are these assumptions? Has a reality check been done on the assumptions?
- There is no clear indication about the makeup of EVs covered by this model and their range and travel patterns (origin, destination). The reviewer questioned the failure to include return-to-base, centralized charging for utility and municipal fleets, rental cars, etc. The reviewer also questioned the failure to include MD and heavy-duty (HD) vehicles in the modeling.
- Consumer input seems to be ignored in the model. What is the willingness of the market of EV owners to pay extra for extra fast charging?
- The PI does not say how the results of the modeling will be tested or corroborated.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Simulation results looks promising. Simulation converges in a reasonable time frame with adequate accuracy. The reviewer was looking forward to some more simulation results to demonstrate how well the proposed smart algorithm can enable the frequency and voltage regulation. Is there any performance difference between different smart algorithms? What are the key merits that the project leader chose to evaluate the smart algorithm?

Reviewer 2:
The "Price Taker" model extended to operate at multiple levels: across vehicles at a charging station, behind the meter, and between meters in a single distribution feeder and between distribution feeders. The charging model implemented and tested is fully decentralized with no central coordination of any kind and supporting ancillary services and multiple competing parties. The Price Taker charging concept is modeled, and simulation results (graphics related to feeders, meters, stations, and EVs) are included in the project report.

Reviewer 3:
The slides on technical accomplishments merely tell us what the model can forecast or simulate depending on the parameters, such as number of iterations, number of feeders, and number of meters. The results of the modeling do not tell us how good the model (algorithm) is nor do the results tell us how close to reality the model (algorithm) is.

Reviewer 4:
The technical approach is good, but the progress appears to have some restrictions to moving forward. It is not clear why this project has ChargePoint as a partner as it seems unwilling to provide project data without being funded separately for this. It is also not clear how reserves and demand response signals are balanced to meet both grid and EV requirements.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration with ChargePoint seems to be sufficient. The reviewer hoped that the data purchase process goes smoothly.

Reviewer 2:
Collaboration with Lawrence Livermore National Laboratory (LLNL) and ChargePoint is indicated. Also, an EVSE manufacturer could provide access to a testbed.

Reviewer 3:
Apparently, ChargePoint's data were expected and hindered due to specific funding, even though the project is funded. Data can still be collected on feeder circuits on EV charging to make some progress.

Reviewer 4:
The project team failed to include an end-user (other than themselves and ChargePoint).

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
It looks like the model would be significantly improved and expanded. The reviewer looked forward to additional solid results to demonstrate that the project is delivering useful and insightful results.

Reviewer 2:
The following relevant tasks are outlined in the Proposed Future Research section of project report.

- Pairing Raspberry Pi proxy with Open EVSE for proof-of-concept
- Incorporating fixed-schedule EV into the model
- Incorporating client (EV) demand function (demand curve)
- Using more extensive simulations, including co-simulation with HELICS and ns3.

Reviewer 3:
It is not clear how using demand response and spinning reserves will meet the customer expectations for fast charging. Future research should include the customer's willingness to curtail fast charging from any demand response action.

Reviewer 4:
Until the project goals and objectives are clarified, the modeling assumptions are delineated, the end-users of the model are identified, the means for verifying the results of the model are proposed, the market for extra fast charging is known, and other shortcomings specified in the technical approach are addressed, the reviewer would not recommend future proposed research on this project.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Yes.

Reviewer 2:
Smart charging that drives the cost of charging lower and faster access to charging station is very relevant to fast adoption of EVs.

Reviewer 3:
The need exists to model and predict fast charging requirements. However, it seems that more EVSE brands need to be included and then expanded to include more than 50 kW) stations.

Reviewer 4:
This reviewer emphasized that the project did not make a clear case for how the modeling is relevant to DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This project has the necessary resources and research funds.

Reviewer 2:
The resources are sufficient, just not the available data from the EVSE resource.

Reviewer 3:
The purchase process between the collaborators makes the reviewer wonder if there is any other way to obtain the data. Can the project leader purchase from another operator to cross check with the results simulated from the ChargePoint data?

Reviewer 4:
The reviewer had no comment.

Presentation Number: elt201
Presentation Title: Charging Infrastructure Technologies: Smart Vehicle-Grid Integration–ANL
Principal Investigator: Keith Hardy (Argonne National Laboratory)

Presenter

Keith Hardy, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

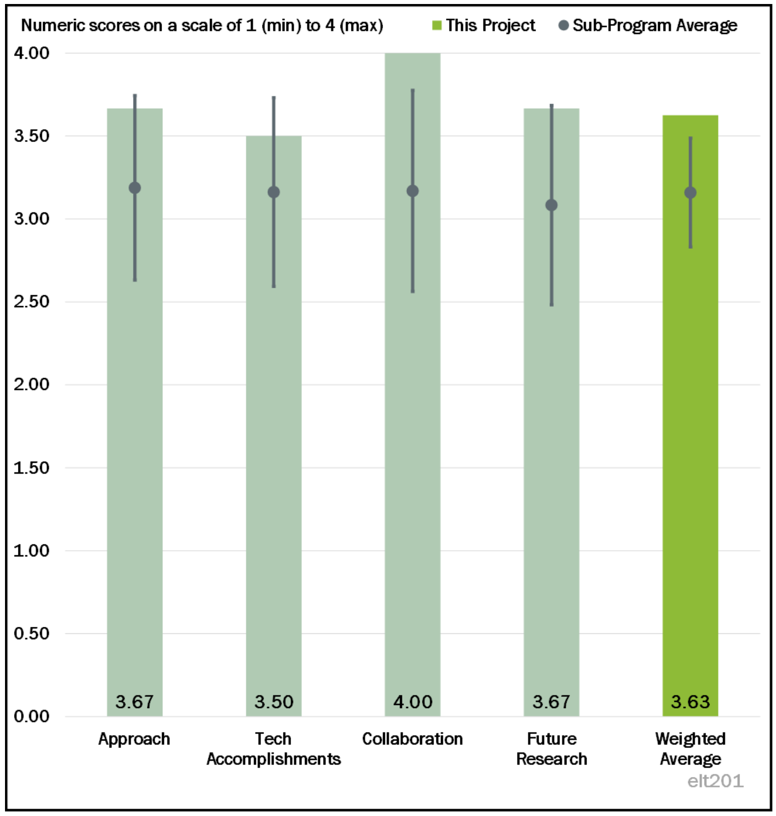

Figure 4-14 - Presentation Number: elt201 Presentation Title: Charging Infrastructure Technologies: Smart Vehicle-Grid Integration–ANL Principal Investigator: Keith Hardy (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The approaches look very solid.

Reviewer 2:
This project has an excellent approach since it builds on previous experience and continues to develop the Energy Management System for vehicle charging and controls for both AC and DC charging systems. This joint laboratory effort is able to demonstrate variations for managing charging systems. Both ANL and Joint Research Center (JRC) laboratories leverage both regions' strengths and allow utilizing systems that are better suited to each but offering common solutions to both regions.

Reviewer 3:
The project tasks (component development, standards work, demonstration) are all appropriate parts of addressing the barriers to smart grid energy management mixing EVs and other energy sources on the electrical grid.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The technical accomplishments and progress are outstanding by addressing challenges of high-power charging to ensure the full capability of vehicle charging is included. This includes the development of the smart charge

adapter to provide a full solution for monitoring the charging communication and grid quality aspects to provide features not included in other projects. The metering project includes validation of equipment and controls required for EVSEs and data to the vehicle OEMs to monitor grid quality items and responses to adjustments from distributed energy resources (DER) commands. The demonstration of various protocols is critical since alternative approaches are required for variations in regions, utility territories, and customer desires that will continue to evolve and change. The flexibility of multiple approaches provides a more viable solution for the results to be implemented to the industry.

Reviewer 2:
Some tasks were hindered by the laboratory closure but appear to be manageable within the current year. Good progress was made on communication and sub-metering hardware.

Reviewer 3:
It would be nice to see some simulation results after adding the XFC and battery storage to the distributed network model. For example, what kind of additional feature and function can this achieve comparing to previous?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project has an impressive array of collaborating companies and organizations, covering the gamut of potential stakeholders. International collaboration is outstanding.

Reviewer 2:
It can be seen that collaboration is coming from all different aspects, including OEMs, EVSE manufacturers, utilities, and many more. The annual update just cannot share all the great results this project has achieved.

Reviewer 3:
ANL has led the collaboration and coordination for North America and insured the teams in other regions are included in this effort. Information exchange of the approach and progress at ANL and JRC laboratories are used to mature and validate the standards for energy management communication and controls.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
ANL has an outstanding position for future research as high power charging systems are still evolving and the capabilities of the Energy Plaza will be able to validate updates to the standards and identify issues that need to be resolved for further updates to improve interoperability of charging systems. The Diagnostic Electric Vehicle Adaptor (DEVA) and sub-metering are continued items for complementing the project that offer OEMs and EVSE supplier tools for coordinating validation at their sites while leveraging ANL’s facilities.

Reviewer 2:
The next steps are appropriate for demonstrating the project's ultimate goals.

Reviewer 3:
It is always great to see any types of demonstration.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Yes, this project supports the overall DOE objective. It is very important to develop and demonstrate the vehicle grid communication and solve the potential problems.

Reviewer 2:
The project aligns with the DOE VTO objective of removing barriers to more widespread EV adoption. Smart EV grid interaction is an important part of managing large numbers of EVs simultaneously connected to the grid.

Reviewer 3:
This project supports DOE objectives by providing a National Laboratory approach for development and validation to improve and expand the communication and equipment standards. Developing diagnostics and metering equipment complements this by providing solutions for the industry.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
ANL has sufficient resources for this project and is able to balance OEM and EVSE supplier needs.

Reviewer 2:
Resources appear to be sufficient to meet the outlined tasks.

Reviewer 3:
It looks like the project leader has sufficient resources to get the milestone achieved. The project leader mentioned the hardware-in-the-loop (HIL) engineer was absent. That might lead to some delay, but the reviewer would trust the team to solve that issue pretty soon.

Presentation Number: elt202
Presentation Title: Charging Infrastructure Technologies: Smart Electric Vehicle Charging for a Reliable and Resilient Grid (RECHARGE)
Principal Investigator: Andrew Meintz (National Renewable Energy Laboratory)

Presenter

Andrew Meintz, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

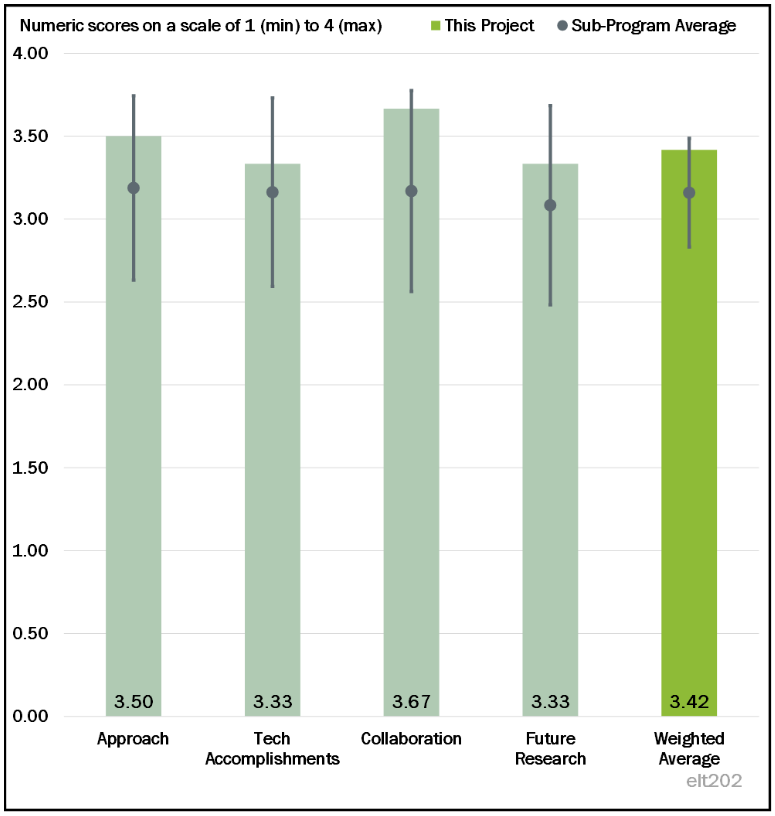

Figure 4-15 - Presentation Number: elt202 Presentation Title: Charging Infrastructure Technologies: Smart Electric Vehicle Charging for a Reliable and Resilient Grid (RECHARGE) Principal Investigator: Andrew Meintz (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project has an outstanding approach for smart charging that is required to balance the grid and vehicle charging requirements. Distribution system modeling provides the background in charging installation to optimize the customer needs with infrastructure actions. This project provides a direct comparison of unmanaged charging against different level of managed charging for two major cities to clearly demonstrate the benefits with accurate data. This project is well designed since it also combines residential and fast charging needs to evaluate the impact of the entire systems.

Reviewer 2:

Using smart technologies, including geo-spatial mapping of grid infrastructure and EV location, the project team wants to understand plug-in electric vehicles (PEVs) at scale with unmanaged charging followed by investigation of managed charging with co-simulation of PEV in the electric grid. It is assumed that managed charging will be assisted by the high-level controls. Finally, using the new control technique, the project team will investigate advanced charge controls with co-simulation of PEV in the electric grid. This approach aligns with project goals to address barriers, which are mainly due to lack of data, such as when and how electric vehicles at scale will impact the grid and how electric vehicle load can “move” throughout the grid under various control and infrastructure scenarios. Once data are available, then reduced-cost electric charging infrastructure can be developed by optimal uses of resources in infrastructure, which is a key ingredient for the rapid adoption and deep penetration of PEVs.

Reviewer 3:
It is reasonable to first look at unmanaged charging and gradually move to more complicated and controlled scenarios. The approach covers a wide variety of tasks. Apparently, task 5 to task 10 will possibly generate some interesting insight and useful deliverables. The reviewer looked forward to seeing these results in more details.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
This project is using charging history as input to predictions on future needs. This balances the planning for additional and changing needs to include vehicle charging in infrastructure plans. Considerations that have included climate effects to grid loads have demonstrated a full approach for aggregators and planners to establish the optimal control and user benefits for balancing vehicle charging needs.

Reviewer 2:
The project team has obtained electric feeder models for Minneapolis and Atlanta and converted these models for simulation and validation in Open Direct System Simulator (OpenDSS). The project team has regular meetings with Xcel Energy and Southern Company to share results and get feedback, has quantified the impact of uncontrolled charging, has refined smart charge control strategies, and has integrated load profile resulted from controlled and smart charging with residential building loads.

Reviewer 3:
The project has successfully achieved the co-simulation between spatial and temporal models. Residential, commercial, and industry feeder examples have been looked into to identify the problem and opportunities. An uncontrolled scenario has been completed. The reviewer rated the project as “excellent” mainly because the detailed results of task 5 “refine smart charge control strategies” have not been well explained. The bullet points only show what has been added or what will be added in the future. The reviewer assumed that the work is still in progress, so rather than presenting an intermediate result, the project leader might just delay the results to show next time in a more complete way, which is fine. The reviewer thought the next year deliverable of this project will have more contributions and generate more novel ideas.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer rated the project as "excellent" because the collaboration seems to be well planned. The grid impact analysis for two different cities is carried out by two different teams, and each will focus on different aspects of the power system. In this AMR presentation, this advantage has not been observed yet. It seems like the two teams are doing identical work and putting out results for comparison. The reviewer is looking forward to the different insight each might have in the future.

Reviewer 2:
This project has demonstrated close coordination with other National Laboratories, utility partners, and vehicle OEMs and through United States Council on Automotive Research and the Grid Integration Tech Team (GITT) interactions. This has established the basis for smart charging and is adding distributed energy resources (DER) functions that will complete the system by adding solar and stationary storage along with DER functions for grid stability.

Reviewer 3:
Collaboration with multiple entities led by NREL team are as indicated:

- NREL— Project lead and developing PEV load profiles, as well as Minnesota OpenDSSmodels
- INL— Co-funded subcontractor to the project, responsible for developing aggregator model
- SNL— Co-funded subcontractor to the project, responsible for developing Atlanta OpenDSSmodel
- Xcel Energy— Providing data from Minneapolis distribution grid to assess loads and hosting capacity
- Southern Company— Providing data from Atlanta distribution grid to assess loads and hosting capacity
- INRIX— Subcontractor providing Minneapolis and Atlanta travel and vehicle data to assess PEV spatial and temporal charging loads
- EDF Renewables— Subcontractor for smart charging system supporting integration with building loads.

In addition to above collaborative activities, the project team also coordinates with the automotive and utility partners through the U.S. DRIVE GITT.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer is looking forward to the future results for task 5 to task 10.

Reviewer 2:
Proposed Future Research topics include: identification of smart charging control strategies, quantification of implementation costs, distribution impact analysis for uncontrolled and controlled scenarios, transmission-level analysis, integration of smart charging with XFC and distributed energy resources, and integration and development into final tools.

Reviewer 3:
Future effort would be to include the DER advanced functions identified in Rule 21 and Institute of Electrical and Electronics Engineers (IEEE) 1547-2018, IEEE 1547.1, and SAE J3072 standards. This project has included the foundation for future research since it uses historical data to predict future expectations while including climate variations that effect loads and resources. This is not ready for advanced functions using DER approaches for grid stability with both AC and DC DER approaches.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Yes, this project supports the overall DOE objectives.

Reviewer 2:
Successful completion of this project will demonstrate the value of smart charge management to reduce the impact of EVs at scale. Smart charging infrastructure will enable rapid adoption and penetration of PEVs.

Reviewer 3:
This project supports DOE objectives by including planning functions for grid stability. The planning and approach are expandable as the quantity of vehicles increase and the management approach is expanded to other locations.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This multi-entity project led by NREL has necessary resources and enough research funds to succeed.

Reviewer 2:
It looks like this project has sufficient resources to achieve the proposed milestones in a timely manner.

Reviewer 3:
This project sufficiently steps through the actions needed to meet current needs while planning for additional growth of the electrification market. This project demonstrates the ability to dynamically adjust and adapt as conditions change due to climate and vehicle availability and usage varies while matching the grid stability functions. National Laboratory resources are imperative to establish the foundation for this analysis and tools that can be then used by aggregators and planners. No single or combined entities in the private sector can accomplish this task.

Presentation Number: elt204
Presentation Title: Charging Infrastructure Technologies: Development of a Multiport, >1 MW Charging System for Medium- and Heavy-Duty Electric Vehicles
Principal Investigator: Andrew Meintz (National Renewable Energy Laboratory)

Presenter

Andrew Meintz, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

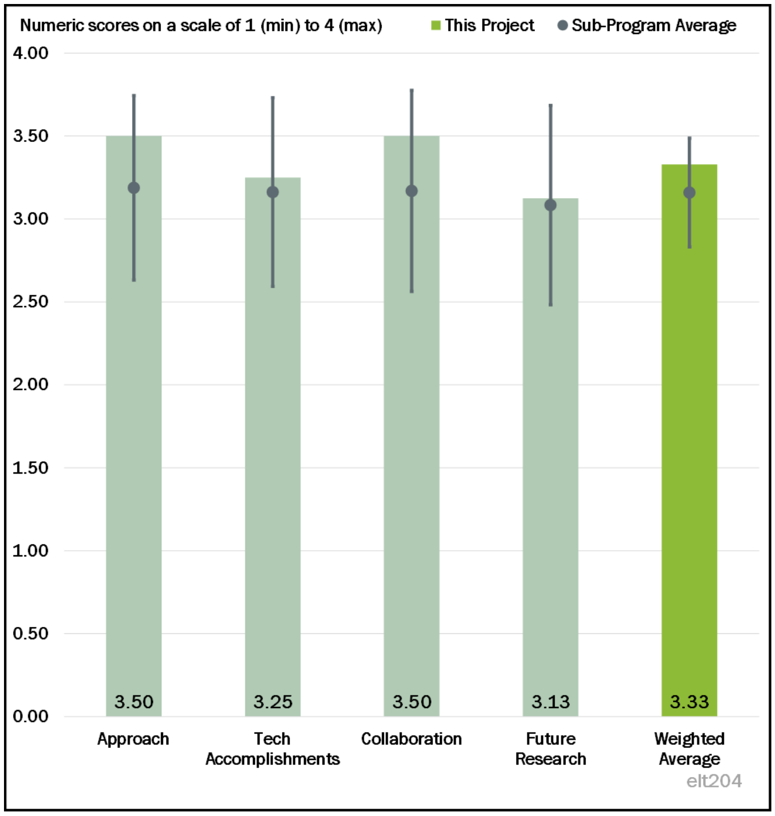

Figure 4-16 - Presentation Number: elt204 Presentation Title: Charging Infrastructure Technologies: Development of a Multiport, >1 MW Charging System for Medium- and Heavy-Duty Electric Vehicles Principal Investigator: Andrew Meintz (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project's objectives and approach toward execution are outlined clearly. The project is currently on track, and the plan for completing the project appears feasible.

Reviewer 2:

The approach is very logical and straightforward.

Reviewer 3:

The project looks as though it has taken into account both MD and HD vehicles, which would be more than likely the ones accessing the truck stops for re-energization. Space seems to be a concern when it comes to the amount of charging equipment needed on site as well as the location of these filling centers, and the power need to sometimes get out to the middle of nowhere.

Reviewer 4:

This project develops an electrical model of distribution feeder with battery energy storage interface along with electric energy generated by a photovoltaic (PV) system. For aggregation of charging energy from three sources (electric grid, battery energy storage, and PV system), a variety of AC-DC and DC-DC and DC-AC power converters is required. The project has taken a collaborative approach with ORNL to develop necessary power electronics infrastructure. Various industries and business owners of charging infrastructure are engaged by the project team for successful execution of approach taken by project team.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Good progress has been delivered toward the final goals.

Reviewer 2:
The technical accomplishments reported for the current period of performance are considerable and well supported. The team has worked on several tasks in parallel and delivered compelling results. Most of the work done to date involved computation (simulations, virtual design, control design, and verification), and as the project approaches the demonstration phase, it would be helpful to get more information on what steps will be taken moving forward.

Reviewer 3:
This reviewer noted power electronics topology for energy sources interface with the battery charger. Power electronics systems such as this, with switching device level design considerations, are likely to result in efficient power conditioning systems to connect multiple sources, which are being reviewed, simulated, and selected by project team. The project team's concept of megawatt plus (MW+) charging equipment and its control systems has evolved to include placing a target for power conversion efficiency. Site utilization (6,284 possible locations were considered in the analysis) and load profile have been investigated by the project team. Based on outcome of the grid impacts analysis, best, mediocre, and worst locations on grid have been identified and marked on Slide 15 of the project report. It seems the closer the location is to the distribution feeder, the better the location is for the MW+ battery charger system. Battery load profile and optimal charge control related project activities were carried out by the team. Design considerations, including thermal management of 1+ MW connector, have been carried with evaluation planned in the fall of 2020.

Reviewer 4:
The reviewer believed the technical accomplishments are very good in concept. The question arises on how much scale can actually be achieved in what is being proposed. The reviewer thought scaling up to accommodate several vehicles at one time would need to be accounted for while attempting to dispense that much energy. How resilient would that be in the middle of the summer, especially for an air-cooled converter?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This project has an impressive amount of entities giving input and all them from the industry that they deal in every day.

Reviewer 2:
The collaboration and coordination across project teams is excellent. The three National Laboratories involved have clear tasks, and a robust coordination plan is in place. There is a remarkable engagement of industry partners.

Reviewer 3:
It is good that many factions are sharing the effort. The team seems to be cohesive and working well together.

Reviewer 4:
Collaboration and coordination were a multi-laboratory approach with multiple industry partners.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future research is clearly explained in the presentation. There should be more discussion regarding which parts of the project will be demonstrated in hardware and how the PI plans to execute the demonstration and evaluate and benchmark the results.

Reviewer 2:
There is a good list of future developments that are required. One development that the reviewer did not see on the list was the effect of high power/fast charge on battery longevity. This is an important effect as we move to higher power charging.

Reviewer 3:
In FY 2020, the proposed future research includes relevant tasks and topics, such as: developing switch-level and average value models to represent charging hardware, demonstrating of charging control optimization for integration with site controller, and supporting charging connector evaluation.

In FY 2021, proposed future research includes relevant tasks and topics, such as: integration of the overall control and virtual 1+ MW multi-port charging system evaluation platform; system verification through control HIL simulation of the charging system response to grid disturbances, effectiveness of site control, and grid interface control capability to mitigating grid impact; and evaluation of power transfer mechanism using prototype hardware.

Reviewer 4:
The steps seem logical, but the project still needs to address getting the power to the site and whether the grid can handle the massive amount of energy required. The grid goes down now without 1 MW fast chargers under light usage from vehicles.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
It supports the DOE objective to move toward cleaner energy. In order to support that objective, charging has to be outside of the home for wider use and for transportation use which has the most emissions.

Reviewer 2:
This project is quite relevant to DOE VTO objective for rapid proliferation of clean energy transportation infrastructure, and the project aims to develop research tools for a framework to design, optimize, and demonstrate key components of a multi-port 1+ MW medium-voltage connected charging system for EVs.

Reviewer 3:
It is important for the future of electric vehicles that we develop high charging and enable vehicles to be used as they are today. Many miles between stops and only short stops are the key to the industrialization of the trucks and commercial transportation.

Reviewer 4:
The project addresses the critical challenge to develop solutions for high power fast charging systems.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources allocated by the partners are deemed sufficient to complete the project.

Reviewer 2:
This project has necessary resources and research funds, and execution of project is being carried out through collaboration and coordination among multiple DOE laboratories and key contributions from multiple industries.

Reviewer 3:
The reviewer did not know for sure, but it seems as though the project is moving forward: therefore, there are sufficient resources.

Reviewer 4:
The reviewer thought the project is well funded but needs to go into another phase after this one has concluded to figure out how to get the energy where it needs to be away from a metropolitan area.

Presentation Number: elt205
Presentation Title: Cybersecurity for Grid-Connected Extreme Fast Charging Station (CyberX)
Principal Investigator: David Coats (ABB)

Presenter

David Coats, ABB

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

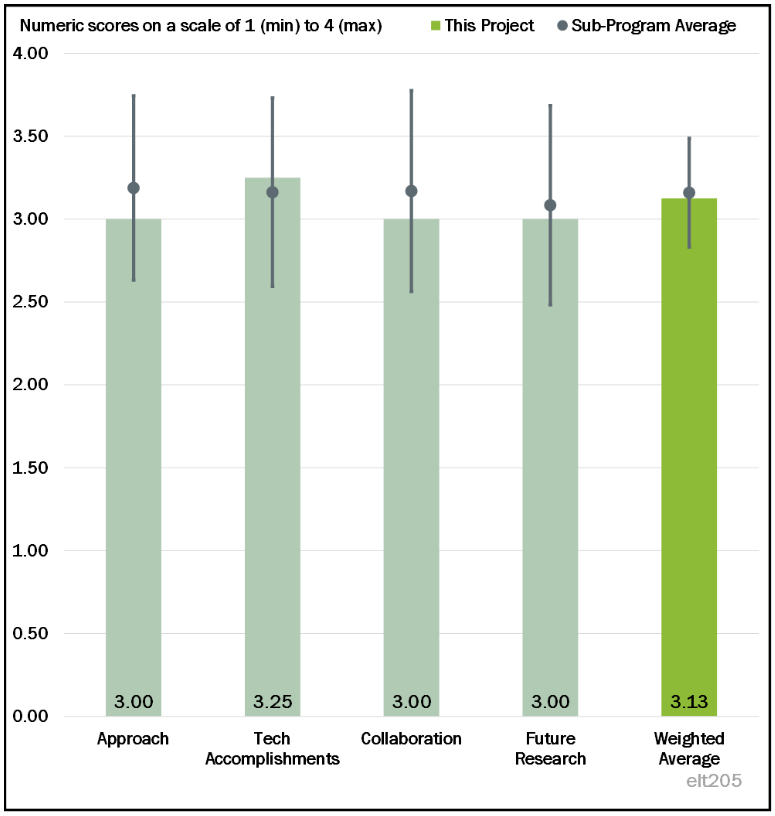

Figure 4-17 - Presentation Number: elt205 Presentation Title: Cybersecurity for Grid-Connected Extreme Fast Charging Station (CyberX) Principal Investigator: David Coats (ABB)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The approach seems logical and systematic.

Reviewer 2:
The overall approach of cyber anomaly detection system (CADS) is good but is not robust enough. It needs to be extended to account for extreme environmental temperatures, sensor bias, and grid parameter anomalies such as voltage and frequency sag.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project technical accomplishments appear to be on track with the project plan.

Reviewer 2:
Good progress was made, but more hardware demonstration is needed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There seems to be a reasonable level of collaboration.

Reviewer 2:
The collaboration and coordination appear to be well executed.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed work is good and systematic.

Reviewer 2:
The proposed future work is logical.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is highly relevant for addressing cybersecurity gaps for high power EVSEs. The project is characterizing threats and prototyping systems to identify and respond to EVSE cyber threats.

Reviewer 2:
Cybersecurity is a key challenge that needs to be addressed.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources are sufficient.

Reviewer 2:
The allocated resources are sufficient for the planned work and timeline in the absence of a pandemic. However, it may be necessary to extend the timeline to account for mandated travel restrictions and supply chain interruptions.

Presentation Number: elt206
Presentation Title: Cybersecurity Platform and Certification Framework Development for Extreme Fast Charging, Integrated Charging, Infrastructure Ecosystem
Principal Investigator: Sunil Chhaya (Electric Power Research Institute)

Presenter

Sunil Chhaya, Electric Power Research Institute

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

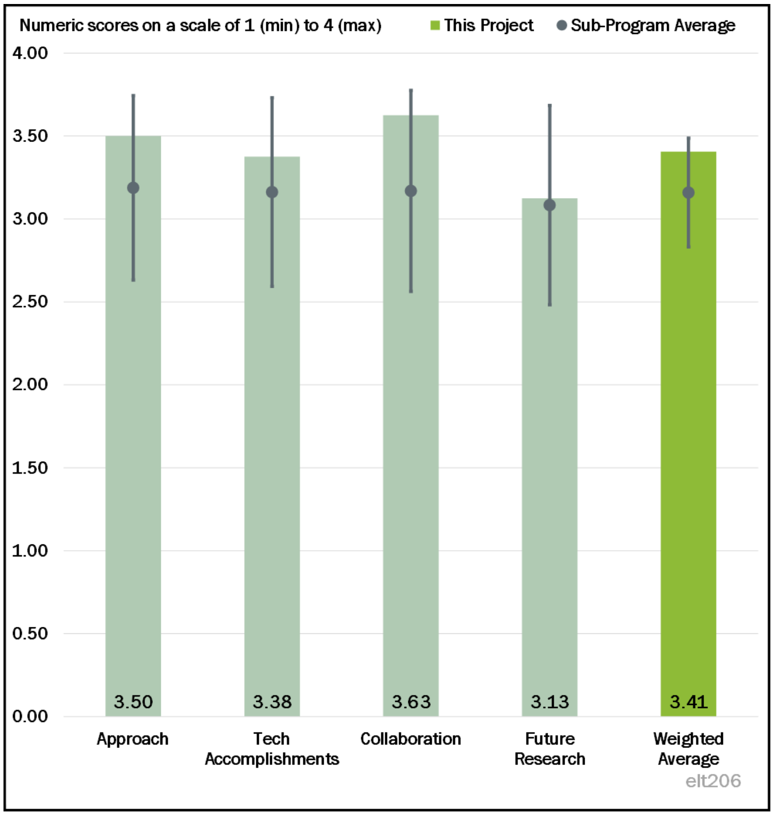

Figure 4-18 - Presentation Number: elt206 Presentation Title: Cybersecurity Platform and Certification Framework Development for Extreme Fast Charging, Integrated Charging, Infrastructure Ecosystem Principal Investigator: Sunil Chhaya (Electric Power Research Institute)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This seems like a very well thought out and executed project with just the verification phase left. The project looks like it took a delay because of COVID-19. The reviewer was interested to see how it comes out.

Reviewer 2:

The work has an excellent diversity of focusing the effort at EPRI and the National Laboratories. Each work group has the ability to work both independently but also toward common approaches and solutions to improving security.

Reviewer 3:

The EPRI approach to this project was well laid out, had the proper perspective to impact the industry, and was flexible enough to be modified to still be productive, given the current environment.

Reviewer 4:

The project design appears reasonably straightforward, if not overwhelmingly innovative, at least as compared to other cybersecurity projects. The team is working with the EV Cybersecurity Working Group as well as federal, state, and utility groups using EPRI for coordination, which will be critical for getting the word out for the results. The project team is looking at much more than just the charging station, including everything attached to the chargers for opportunities for threats.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project and objectives at this point appear to have been met, and the project team is waiting for the verification stage.

Reviewer 2:
This adds value by including unresponsive service or injecting misinformation since that potentially leaves multiple customers stranded at charging stations or provides incorrect information as to the status and use of the charging stations. This project also includes attacks coupled with the customer's phone applications that are used and provided by the vehicle OEM or charge point operator.

Reviewer 3:
The risk matrix was completed, the working group created, and vulnerabilities and threats identified during BP 1. The current phase is focused on developing the security test plan. Some of the testing has been delayed due to COVID-19, but the PI does not expect that this will impact the overall schedule for the project as several activities are shifting around to attempt to keep the schedule reasonably on track. A key development during the project is the network interface card (NIC) for use in reducing cybersecurity risks, which the team plans to make open sourced to allow for greater adoption.

Reviewer 4:
There is a good foundation for cyber. A little more detail about subsystem requirements and industry acceptance would have been good to report out on.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
These project teams have an excellent history of joint effort and positive results. The teams have separated each task to complement their capabilities and maximize their contribution to successful completion of this project and will lead to future effort as security requirements continues to evolve.

Reviewer 2:
This project makes good use of partnership resources as well as bringing reviewers' comments into the process and has had industry impact with MD-HD cyber infrastructure. The internal review process helps to keep the project focused on advancing cyberstability.

Reviewer 3:
The makeup of the project team seems good, including laboratories, vendors, and a charging site supplier. Each organization appears to have clear assignments. The team's plan to coordinate through industry working groups and government/utility teams for information dissemination is a benefit. The team is also coordinating with the other VTO cybersecurity teams.

Reviewer 4:
All the proper people and groups are in play for the project. The reviewer wondered why it is only geared toward XFC cybersecurity and not all charging systems.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
This initial effort is applicable to expansion as other charging stations and more EVs come to market with more variations to consider. The foundations created on this project can be applied to other suppliers and expanded as the charging features also continue to grow and expand.

Reviewer 2:
The project team seems to have a plan for future research focused primarily on developing a NIC prototype and testing security controls in real-world applications.

Reviewer 3:
Looking at the future plans, the reviewer would probably test in a real-world scenario first before publishing outcomes.

Reviewer 4:
The project needs to have a proper test plan with appropriate asset impact levels of stability so that partner resources may be properly allocated.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is extremely relevant as cyber impacts many parts of the next generation transportation systems.

Reviewer 2:
The grid and charging structure are very crucial to the security of the country, and it is very important to possibly come up with a standard for protecting it.

Reviewer 3:
The project is addressing cybersecurity for EV charging systems, a critical step required for success of EVs in the marketplace.

Reviewer 4:
This project allows the analysis of existing standards to be evaluated and improved upon. While each of the teams approach this from different angles or aspects, more solutions can be realized from a project with less diverse and smaller teams.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources appear sufficient at this time.

Reviewer 2:
The project team has made good progress with resources available and is on track to meet project objectives.

Reviewer 3:
The reviewer saw no issues with how the project is proceeding with resources at this time.

Reviewer 4:
EPRI and National Laboratories have the equipment and resources to accomplish this task. Additional vehicles and chargers are always harder to include, but as production and diversity continues, this will be more sufficient in future projects.

Presentation Number: elt207
Presentation Title: Enabling Secure and Resilient Extreme Fast Charging: A Software/Hardware Security Co-Design Approach
Principal Investigator: Ryan Gerdes (Virginia Tech University)

Presenter

Ryan Gerdes, Virginia Tech University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 33% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

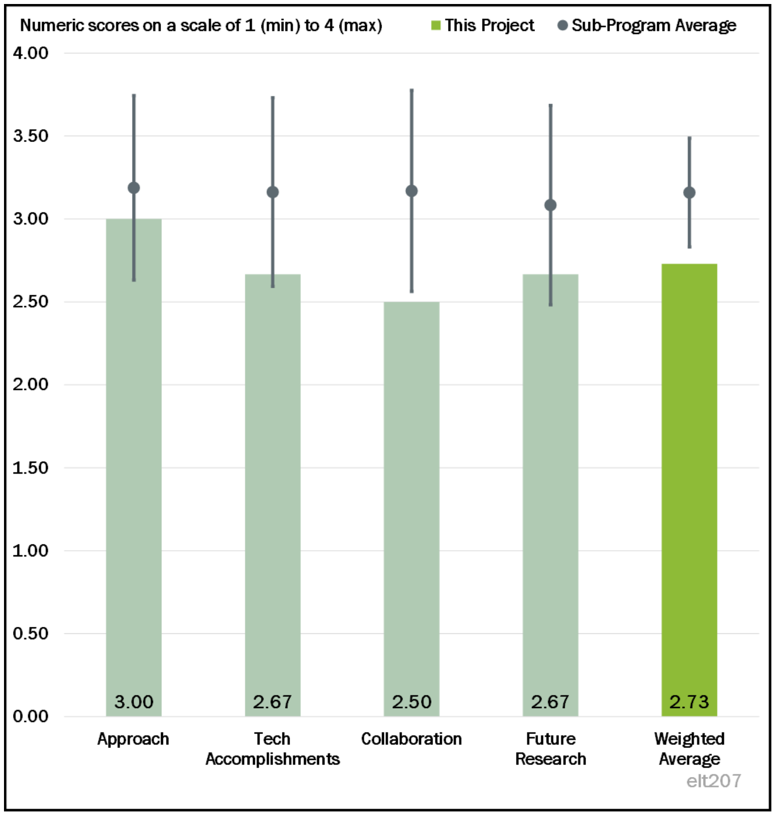

Figure 4-19 - Presentation Number: elt207 Presentation Title: Enabling Secure and Resilient Extreme Fast Charging: A Software/Hardware Security Co-Design Approach Principal Investigator: Ryan Gerdes (Virginia Tech University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach is excellent since it includes networked and centrally controlled charging stations that aggregate the power to multiple vehicles from a central controller. This adds the sub-controlled or micro-grid aspect to a charging station plaza that also includes multiple single charging stations. This scenario is highly likely with high power chargers and adds a level of security to this project.

Reviewer 2:

The project made good use of developing threat scenarios, identifying threat priorities, and use of threat assessments. The scope of the project seems to be very large for the team. This was noted by previous reviewers. Perhaps a remapping of goals would be appropriate, given COVID-19 impacts on the project.

Reviewer 3:

The approach seems promising. However, considering current progress of the project and proposed future research for the rest of 2020, it seems very challenging, even considering a 6-month extension due to COVID-19.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
This project has made excellent technical progress on the modeling and planning but is delayed due to equipment deliveries that could have been utilized earlier in the timeline. The models and approach are complete, but the demonstration and evaluation seem to be delayed from the initial planning.

Reviewer 2:
Good progress was made with simulation and software threat approach methods, but hardware (impacted by COVID-19) and through vehicle selection (a vehicle which is incapable of XFC charge rates) will reduce effectiveness of testing and the results will be biased. It will be interesting to see attack vectors prioritized based on impact to the system. Some hardening approaches should be evaluated by third parties on a separate system to see if approaches have merit.

Reviewer 3:
The progress is stated as 55% which is well behind schedule. The concern about the progress and being behind schedule was also raised during the previous round of reviews.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There is excellent coordination across the teams since all members have diverse functions and focus. The combination of actors in this scenario provides an accurate and complete approach to completing the project goals. The effort of three universities along with industry sectors provides the mix of talent and approaches for positive results.

Reviewer 2:
This reviewer observed good member coordination, but as described there are still barriers with cross team knowledge of various domains. Because the scope is quite large, perhaps some focus on a specific (and reduced) attainable goal set would yield better results.

Reviewer 3:
The tasks, workload, level of involvements, and accomplishments of each collaborator need to be clearly and accurately mentioned, which are missing.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Future effort is always needed to view new functions and features as these are applied to charging equipment and vehicles. Additional charging station suppliers and utilities along with more OEMs will add to the inputs to validate results of this project and lead to additional items that need to be considered.

Reviewer 2:
Linking proposed future work to changes in funding needs to be updated with background on project spends and missed milestones due to barriers or other challenges.

Reviewer 3:
The future research plans look promising; however, it seems very challenging to be completed on time, even considering 6-month extension due to COVID-19.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The objectives outlined here match well with the priorities of DOE.

Reviewer 2:
This project is relevant since it combines existing DC charging stations with high power stations that aggregate loads within multiple dispensers. This mix of product is typical of current deployment of equipment and vehicles and sure to improve the approach to security for the industry to apply.

Reviewer 3:
The topics of the project are relevant, but the ability to complete objectives has impacted the project's relevance. Completion of focused milestones (a reduction from the original scope) would help the project have meaningful impact.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources are sufficient for a reduced and focused goal set. The project team needs industry input to identify the most viable milestones, and effort should be focused on those.

Reviewer 2:
Resources are sufficient for the start of this approach. Expansion to other suppliers and charge point operators along with additional utilities is a key to maximizing input for a robust solution and needs to expand to include more of these variations.

Reviewer 3:
Considering the project objectives and future research and plans, the allocated budget seems more than enough.

Presentation Number: elt208
Presentation Title: Highly Integrated Power Module
Principal Investigator: Emre Gurpinar (Oak Ridge National Laboratory)

Presenter

Emre Gurpinar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers indicated that the resources were sufficient, 25% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

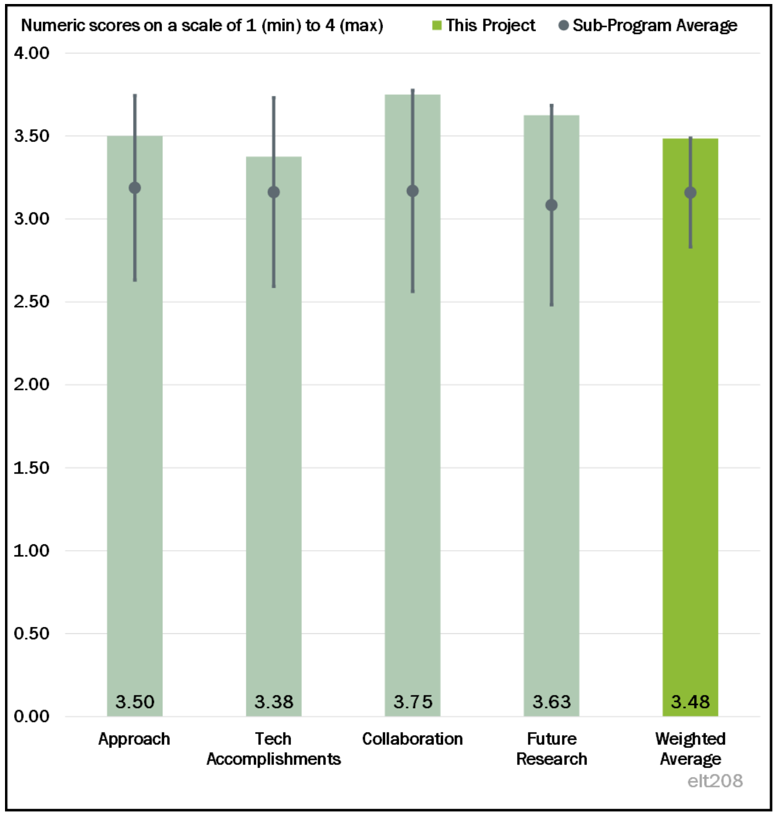

Figure 4-20 - Presentation Number: elt208 Presentation Title: Highly Integrated Power Module Principal Investigator: Emre Gurpinar (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The presenter described a comprehensive approach tackling key aspects of design to enable reaching the target.

Reviewer 2:

Some of the previous work at ORNL is well utilized. Also good is that both silicon carbide (SiC) and gallium nitride (GaN) are considered.

Reviewer 3:

Thermal management is critically important to the performance, reliability, and cost of power modules. Thus, it is crucial to tackle the challenge by finding a materials solution to effectively extract heat away from the heat-generating device and transfer it to the environment through an efficiently designed heat sink. This project is aimed at finding solutions to both.

Reviewer 4:

To meet the DOE VTO 100 kW/liter (L) power-density target, a high-performance power-dense SiC power module is required. The project team is attempting to address 2025 power-density, cost ($2.70/kW), peak efficiency (greater than 97%), reliability (300,000-mile lifetime or 15 years operational life) targets by a SiC power module that has improved heat extraction, enhanced thermal and power cycling capability, low electrical parasitics, and integrated gate driver, sensor and protection circuits. It is a compelling approach to meet DOE VTO objectives and targets. Automated Design of Power Electronics and selection of one of best between GaN and SiC devices is also part of the project approach and strategy for a successful outcome of this project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The research team completed extensive simulations of the thermal performance of insulated-metal substrates with and without thermal pyrolytic graphite (TPG) as well as development of a liquid-cooled heat sink optimization scheme. The team has also made significant experimental progress to validate their simulation studies.

Reviewer 2:
The project team has completed the following technical tasks that will lead to successful completion of this project:

- Prototyping of direct bonded copper (DBC), insulated metal substrate (IMS), and IMS with TPG core (IMSwTPG) substrates
- Development of test setup for thermal and electrical characterization of half-bridge SiC power modules
- Comparison of steady state thermal performance based on experimental characterization
- Analysis of current capability and heat spreading of different substrates
- Transient thermal analysis of DBC, IMS, and IMSwTPG
- Electrical characterization of IMSwTPG
- Development of liquid cooled heat sink optimization scheme for automated design for power electronics
- Recommendation of multi-layer organic film based direct bonded copper (ODBC) substrate for optimized power module
- Analysis of layer thickness for multi-layer ODBC substrate
- Design of integrated heat sink for multi-layer ODBC substrate
- Development of a test board for characterization of GaN high-electron-mobility transistor (HEMT) and SiC metal oxide semiconductor field effect transistor (MOSFET) for traction drive systems.

Reviewer 3:
The project documented well the design, simulation, and experimental results. Experimental results are not reflecting steady state temperature similar to simulation results. It would be critical to identify for evaluation the impact on the reliability objective.

Reviewer 4:
Good progress is shown in analyses, design, and optimization task items. Also, some experimental characterizations have good progress. It may or may not be under the scope of this particular project, but the switching transient associated high-frequency oscillations on Slide 11 will sooner or later become a major concern. It might be a good idea to start giving specific thought to how to handle that from the packaging viewpoint (module parasitics and semiconductor capacitance).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Multiple National Laboratories, multiple universities, and multiple industries—collaborations are excellent!

Reviewer 2:
The complementary expertise of the partners and close interactions across the project team show a strong cohesive and synergistic collaboration.

Reviewer 3:
The project team was strong with well-defined independent roles.

Reviewer 4:
Many academic institutes, industries, and DOE laboratories are part of overall team with leading roles and responsibilities in successful execution of project tasks and completion of project milestones.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Having completed extensive theoretical and simulation analyses and construction of a testbed for experimental implementation, the team's plan to focus on assembly, prototyping, and testing is logical and timely to further advance the goal of the project.

Reviewer 2:
The presenter defined milestones for FY 2020 and FY 2021.

Reviewer 3:
Future research topics that are going to make this project a successful one include the following:

- Complete assembly of test board for GaN HEMT and SiC MOSFET
- Complete the optimization of high-performance heat sink for multi-layer ODBC module based on GaN HEMT and SiC MOSFET
- Simulate the electrical and thermal performance of organic substrates with SiC and GaN devices
- Finalize the design for integrated module based on multi-layer ODBC
- Complete experimental characterization of SiC MOSFET and GaN HEMT
- Fabricate prototype integrated power module based on multi-layer ODBC
- Develop a segmented three-phase inverter based on proposed concept.

Reviewer 4:
The hardware prototyping and test plan are good. The reviewer looked forward to hearing about the prototype test results. It might be beyond the scope of this particular project, but it would be even better if specific consideration were given to extending the concept in this project to the double-sided cooling.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Power-dense SiC and GaN power modules are closely tied to DOE objectives for cost-effective, high-reliability, high-efficiency, and miniaturized power electronics.

Reviewer 2:
The technologies developed in this project are key for achieving DOE Electrification Technologies' (ELT's) 2025 technical targets for electric drive systems.

Reviewer 3:
Yes, project ELT208 is relevant in order to meet the challenging inverter power density target in the U.S. DRIVE Electrical and Electronics Technical Team (EETT) roadmap.

Reviewer 4:
Power density and cost optimization were indicated by this reviewer.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This project has necessary resources and research funds, and collaborations seem to be working smoothly.

Reviewer 2:
There are sufficient resources with no redundancies.

Reviewer 3:
Utilizing the outcomes and facilities handed over from the previous projects, it looks like resources are sufficient.

Reviewer 4:
The project addresses both scientific and technological challenges of a complex systems problem. More funding to the project team would ensure the highest possible quality of its performance.

Presentation Number: elt209
Presentation Title: High-Voltage, High-Power Density Traction-Drive Inverter
Principal Investigator: Gui Su-Jia (Oak Ridge National Laboratory)

Presenter

Gui Su-Jia, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

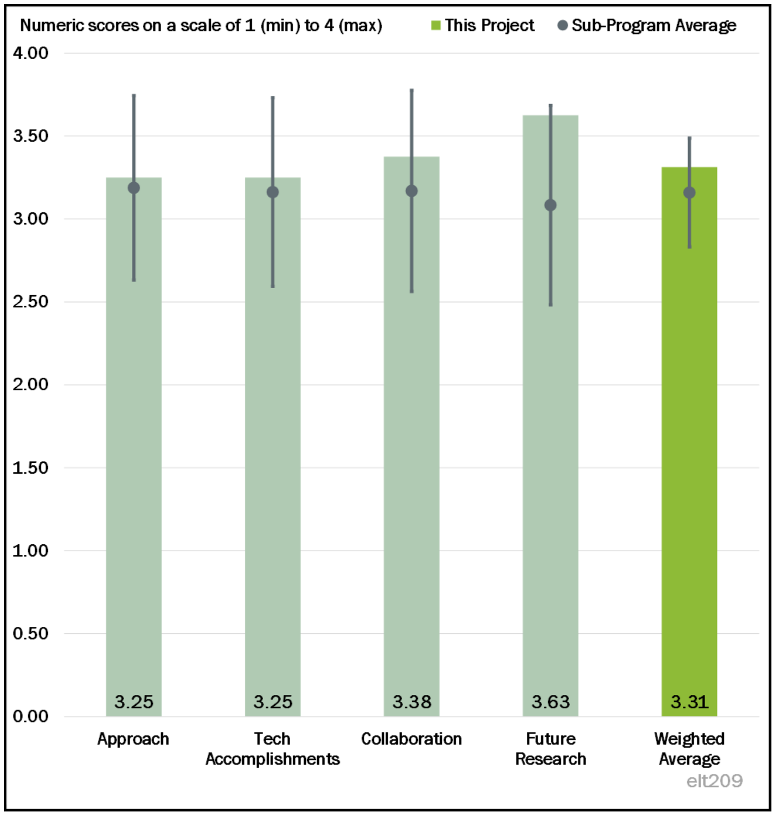

Figure 4-21 - Presentation Number: elt209 Presentation Title: High-Voltage, High-Power Density Traction-Drive Inverter Principal Investigator: Gui Su-Jia (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The PI's previous work appears to be well utilized. As mentioned in the question and answer session of the oral presentation, the reviewer looked forward to hearing about the follow-up regarding comparative evaluation between the segmented inverter drive and the open-end winding dual inverter drive concept.

Reviewer 2:

Passive elements, such as the decoupling capacitors of the electric-drive inverter, take up a large volume. To meet the ambitious 100 kW/L target prescribed by the ELT program, the team developed an innovative approach by segmenting the existing three-phase into a two, three-phase topology. As a result, the capacitor size is cut down by half, thus making a significant contribution to boosting the power density of the drive.

Reviewer 3:

The project PI assumes that DC capacitor cost can be drastically reduced by using active cooling of a segmented inverter DC bus bar. The segmented inverter allows interleaved pulse width modulation (PWM) switching of all devices in both inverters, resulting in significant reduction in DC bus current ripples. Capacitor elements are embedded, distributed, and direct cooled. The reviewer indicated a multiple prong approach from the standpoint of packaging, thermal management, and control of the segmented inverter, resulting in an inverter that could get closer to DOE VTO target for power density, cost, efficiency, and reliability.

Reviewer 4:

The impact to cost and power density is not clearly stated with proposed approach.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The research team completed extensive simulations of their segmented three-phase inverter approach, developed a robust control methodology, and laid out a design of testbed for experimental verification.

Reviewer 2:
Good progress has been shown in particular about capacitor thermal analysis and simulation. As one of the future task items, cross-comparison between the analyses and simulations and a certain hardware measurement (at least some workbench measurements for several representative operating conditions) is expected.

Reviewer 3:
Technical accomplishments include: development of a switching timing-based method for computing the inverter capacitor ripple current and bus bar current and implemented in MATLAB, development of a driving cycle-based DC bus capacitor life-expectancy prediction and sizing tool, development of a capacitor transient thermal impedance model, and development of direct-cooled bus bar design concept. These outcomes show that the project is tracking as expected.

Reviewer 4:
Efficiency evaluation is not observed as an accomplishment nor stated to be part of the future work.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There is clear cohesion and synergistic collaboration across the project team.

Reviewer 2:
The presenter clearly stated collaborators and responsibilities.

Reviewer 3:
NREL and Virginia Polytechnic Institute (Virginia Tech) are collaborators with targeted roles and responsibilities in this project led by PI at ORNL.

Reviewer 4:
Collaboration with a National Laboratory (NREL) and a university (Virginia Tech) is well taken. It would be even better if there were some involvement from industry.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future research plan is clear and sound.

Reviewer 2:
The reviewer was looking forward to hearing about the upcoming results of the directly cooled bus bar in 2020 and further looking forward to seeing the outcomes of 100 kW prototype!

Reviewer 3:
The future research tasks include valuation of the impact of the direct-cooled bus bars on the DC bus capacitors in various power modules; finalization of a direct cooled DC bus bar design for use in an inverter prototype in FY 2021; design of a 100 kW high voltage, segmented inverter using ORNL power modules; evaluation of the design against the DOE ELT 2025 targets; and fabrication of a prototype.

Reviewer 4:
The path to evaluating all of the DOE targets (efficiency and cost, specifically) was not observed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Yes, this work is very relevant to meet the challenging target of the power density of 100 kW/L.

Reviewer 2:
The technologies developed in this project are key for achieving DOE ELT's 2025 technical targets for electric drive systems.

Reviewer 3:
Project activities are related to DOE 2025 power electronics objectives and targets for power density, cost, efficiency, and reliability.

Reviewer 4:
Reliability was stated by this reviewer.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Based on the budget number on an early slide in the presentation, the progress made thus far, and the future plan, the budget looks sufficient.

Reviewer 2:
This project has the necessary resources and research funds with appropriate level of collaboration.

Reviewer 3:
The project has sufficient resources with no redundancies.

Reviewer 4:
The project addresses key technological challenges of a complex systems problem. More funding to the project team would ensure the highest possible quality of its performance.

Presentation Number: elt210
Presentation Title: Development of Next-Generation Vertical Gallium-Nitride Devices for High-Power Density Electric Drivetrain
Principal Investigator: Greg Pickrell (Sandia National Laboratories)

Presenter

Greg Pickrell, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

80% of reviewers indicated that the project was relevant to current DOE objectives, 20% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers indicated that the resources were sufficient, 20% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

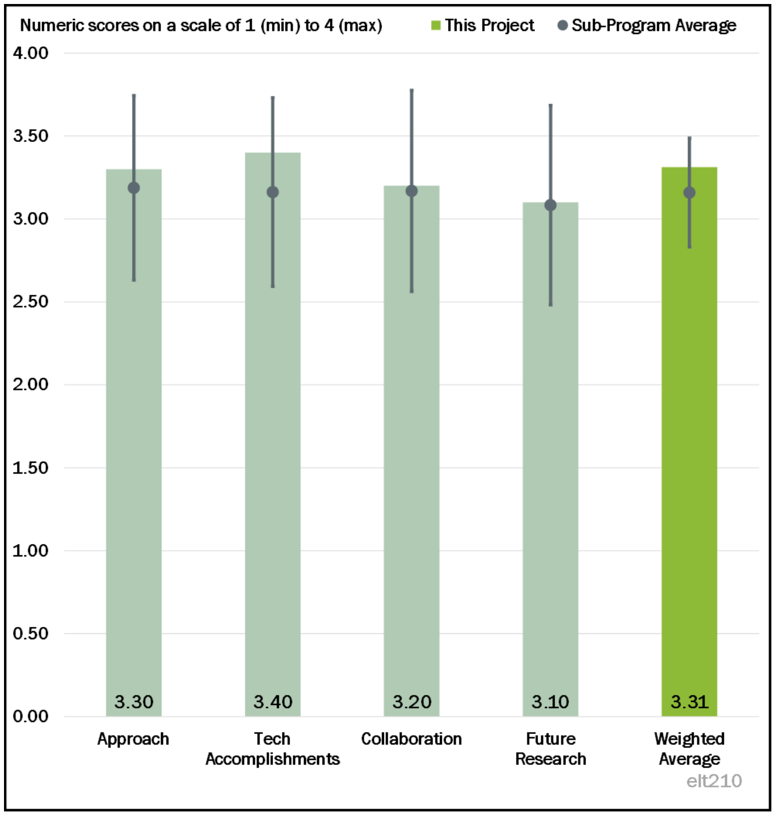

Figure 4-22 - Presentation Number: elt210 Presentation Title: Development of Next-Generation Vertical Gallium-Nitride Devices for High-Power Density Electric Drivetrain Principal Investigator: Greg Pickrell (Sandia National Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The step-by-step approach of a SiC MOSFET /SiC Schottky barrier diode (SBD)to SiC MOSFET/GaN SBD (or junction barrier Schottky [JBS] diode?) hybrid to GaN MOSFET/GaN SBD (or JBS diode?) is good. Developing vertical GaN SBD, JBS diode, and MOSFET are of very strong interest.

Reviewer 2:

The project PI has laid out the importance of enabling a power-dense, cost-effective electric drive system by improving power devices, passive (filter between inverter and electric motor) and rotatory (electric motor) components. Then, the PI down-selected impactful contribution made by the project team in the area of power-dense, wide bandgap (WBG) power devices. This contribution will be made in three stages:

- Stage 1: SiC MOSFET + SiC Diode
- Stage 2: SiC MOSFET + GaN Diode
- Stage 3: GaN MOSFET + GaN Diode.

At each stage, two key tasks are planned in approach taken for execution of this project: Task 1: Device modeling, circuit simulation at each stage and Task 2: Characterization and evaluation of device technology in test bed at each stage. This approach seems appropriate and closely tied with the final objective, “Development of Next-Generation Vertical GaN Devices for High-Power-Density Electric Drivetrain.”

Reviewer 3:
There is a three-step approach in characterization and evaluation.

Reviewer 4:
The team strives to reduce the size and weight of the inverter power electronics of electric drive systems by developing power device technologies based on SiC and GaN that have more superior performance characteristics than today's Si technologies. The SiC device technologies have been in development for over 30 years, and only recently, they are beginning to enter the transportation market. The primary reasons for the slow entry are cost and reliability, both are equally if not more challenging for developing the GaN device technologies. What would be great is if the team offered a value proposition of their vertical GaN devices in electric drive systems.

Reviewer 5:
It is not clear what or if any consultation has been performed with chip manufacturers and vehicle OEMs. This creates uncertainty that the approach is working on the issues that matter for vehicle electrification. The reviewer was afraid this work is focused on what the PI sees as issues, with the underlining assumption being that the chip manufactures not working chip issues currently.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer found the technical accomplishments and progress to be comprehensive.

Reviewer 2:
SiC MOSFETs device gate oxide liability test results and short circuit capability tests are informative! Parametric study of new SiC MOSFET design is also good. Vertical GaN SBD, JBS diode, and MOSFETs study is also informative.

Reviewer 3:
Technical accomplishments of project are detailed out in Slides 7 to 17 of the project report with summary as stated here:

- The project team has pursued multi-path approach for power electronics keystone through development of SiC and GaN devices to meet Consortium targets.
- The project team has evaluated commercial SiC MOSFETs for reliability assessment while starting custom device fabrication at a commercial foundry (university partners). First round of custom SiC MOSFETs showed good device performance. Future designs will focus on automotive requirements.
- GaN device development is underway.
- Extensive device simulations for GaN diodes and MOSFETs have been completed.
- GaN Schottky diodes and JBS diodes have been demonstrated. Optimization is in progress.
- Process development for GaN MOSFET is underway.
- Implanted n-type source contacts for double-well MOSFETs have been demonstrated.

Reviewer 4:
In presenting the technical achievements and progress, the team had a large portion of the achievements made by its partners, OSU, State University of New York Polytechnic (SUNY Poly), and Lehigh University. Although this seems to show a close collaboration between the team and its partners, it obscures the team's own achievements on vertical GaN devices. The team clearly has made significant progress toward epitaxial growth of GaN on GaN and succeeded in fabricating vertical Schottky GaN diodes. Also, it would be great if

the team offered a comparison of their GaN devices with those reported in the literature to stress the significance of their achievements.

Reviewer 5:
Evaluation of off-the-shelf devices provides a good basis for components that are generally available, but the auto OEMs are provided components that are not available to anyone else. If the purpose of this work is for general education of the public, it has value. The reviewer would suggest that the PI contact the ELT082 PI.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Clearly stated collaborators and responsibilities were observed by the reviewer.

Reviewer 2:
This reviewer listed the following project collaborators with specific roles and responsibilities:

- ORNL–Collaborating partner for Electric Traction Drive integration and evaluation
- NREL–Collaborating partner for Electric Traction Drive integration and evaluation
- SUNY Poly (Woongje Sung)–Fabricating SiC JBS diode integrated with MOSFETs (sub-contractor)
- OSU (Anant Agarwal)–Designing for improved reliability for SiC electronics and, evaluating reliability and ruggedness of commercial and fabricated devices using realistic scenarios (sub-contractor)
- Jim Cooper–Working with OSU for SiC device evaluation and SNL for GaN power electronic device design and characterization (sub-contractor)
- Lehigh University (Jon Wierer)–Working with SNL for design, simulation, and modeling of GaN SB and JBS diodes (sub-contractor).

Reviewer 3:
Multiple National Laboratory and university collaborations are good. It would be even better if there would be some industry collaborators.

Reviewer 4:
There are close interactions across the project team to show a strong cohesive and synergistic collaboration. As the team has already realized, adding a partner with packaging expertise would further strengthen the collaboration.

Reviewer 5:
Collaboration with just universities and National Laboratories does not provide the reality/context of what is currently going on the industry.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The next steps of both SiC and GaN are clearly defined. They are good. Also good are clear understandings of the upcoming challenges (automotive environment and cost). Looking forward to hearing about the upcoming year's progresses! Wondering if not only commercially available devices, but also the newly designed/developed devices are also put in the reliability tests. Also, would like to hear about details of gate dielectric material selection for the GaN MOSFETs in the future.

Reviewer 2:
The proposed future research on GaN are ambitious, but are logical continuation of the progress made thus far. This reviewer was confused by the future research for both SiC and GaN devices. Is this project supposed to focus on vertical GaN devices and the team's partners, SUNY Poly and OSU, on SiC devices? Do SUNY Poly and OSU have their own separate projects on SiC devices?

Reviewer 3:
The plan seems appropriate if the work aligns with actual needs from the chip manufacturers and vehicle OEMs.

Reviewer 4:
The reviewer offered the following comments for SiC MOSFETs:

- Focus on design and test for automotive reliability
- Fabricate and test second generation of devices
- Performance targets 1,600 volt (V) holdoff, Ron,sp is 5 mΩ-centimeter squared (cm^2), Vth = 2V
- Evaluate performance against Consortium targets
- Utilize devices in Gen1 prototype Electric Traction Drive.

Regarding GaN field effect transistors, the reviewer indicated the following:

- Iterate to improve GaN JBS diode performance to 600 V holdoff voltage, 0.5 A forward current
- Combine GaN JBS diode with SiC MOSFET in circuit for evaluation
- Demonstrate GaN MOSFET device performance (100 V holdoff voltage, 0.2 A forward current)
- Iterate to improve GaN SB and JBS diode performance against targets (1,200 V/100 A)
- Iterate to improve GaN MOSFET performance against targets (1,200 V/100 A)
- Combine GaN MOSFET and JBS diode in circuit for evaluation.

Reviewer 5:
This reviewer referenced Slide 21 regarding performance to 600 V hold-off voltage. This voltage level was unclear to the reviewer when the performance target is mainly at 1200 V and 1600 V.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
WBG devices are the key role players to meet the challenging power density target of the inverter. Yes, ELT210 is a very relevant project.

Reviewer 2:
To achieve DOE Electrification’s 2025 technical targets for electric drive systems, the device junction temperature will have to be elevated to 200°C or 250°C. This rules out the existing Si devices and awaits the development of either SiC or GaN devices.

Reviewer 3:
Vertical GaN power devices are very relevant for automotive applications and also as alternatives of SiC power devices. This project is striving to address this objective of DOE VTO.

Reviewer 4:
Reliability.

Reviewer 5:
The reviewer would be surprised if chip manufactures and OEMs are not already addressing the issues this project addresses. A detailed review should be held with chip manufactures and OEMs before moving forward on this project.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
For basic understanding and experimentation then the resources allocated are adequate. If the issues identified by this project are validated by the chip manufactures and vehicle OEMs and the goal is to have something that is usable by the OEMs then the resources for this project would be insufficient.

Reviewer 2:
Sufficient resources with no redundancies.

Reviewer 3:
Based on the progress thus far and the plan for the next step with the budget number, it seems sufficient.

Reviewer 4:
A serious development effort for vertical GaN devices, diodes, and switches, is an expensive endeavor. The private sector has already invested tens of million dollars, and the progress has been slow.

Reviewer 5:
Project has-necessary resources and research funds. A multi-entity collaboration seems like it is working in successful execution of project tasks.

Presentation Number: elt211
Presentation Title: Power Electronics Thermal Management
Principal Investigator: Gilbert Moreno (National Renewable Energy Laboratory)

Presenter

Gilbert Moreno, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers indicated that the resources were sufficient, 25% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

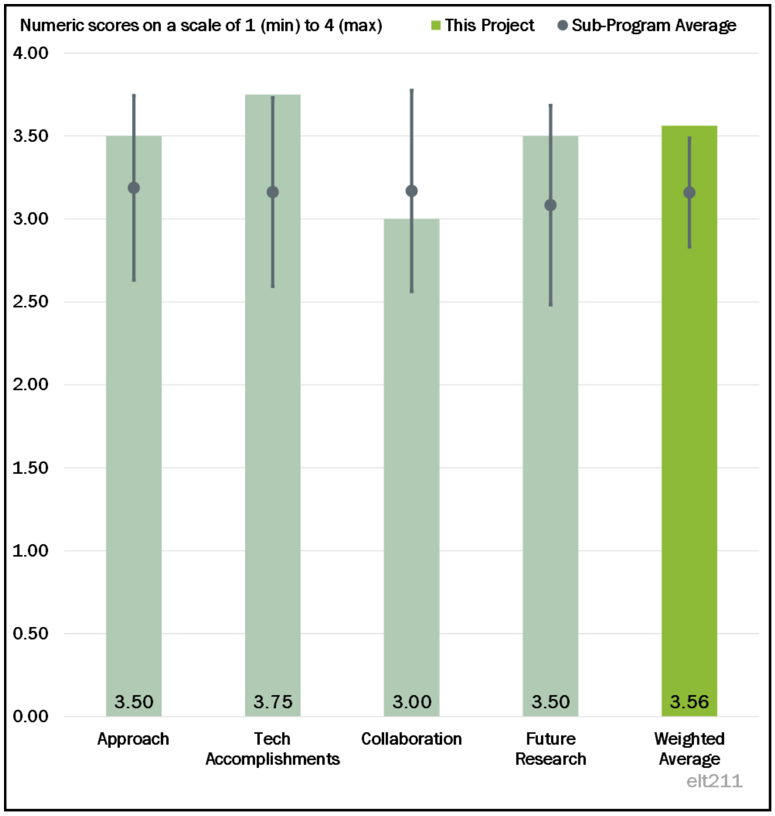

Figure 4-23 - Presentation Number: elt211 Presentation Title: Power Electronics Thermal Management Principal Investigator: Gilbert Moreno (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Effective heat extraction from switching devices is critically important to the performance, reliability, and cost of power modules. The proposed approach offers an innovative strategy for heat removal by flowing a dielectric fluid directly on the device interconnect, either in a single-side or double-side cooling configuration.

Reviewer 2:

The approach seems reasonable and well thought out. The reviewer liked that the focus is outside of what one would expect most OEMs and their suppliers to pursue.

Reviewer 3:

The project is on track with the schedule; the technical accomplishments indicate that the technical barriers have been successfully addressed.

Reviewer 4:

The project team identifies that a compelling, yet practical thermal management strategy is required to achieve power density of 100 kW/L. This strategy includes packaging and convective cooling of power devices including use of the dielectric-fluid for cooling. From past works carried out by project team, it is stated that:

- By reducing the package thermal resistance, the total thermal resistance of power devices can be reduced by approximately 60% to 80% compared to conventional modules.

- Dielectric fluids enable a package re-design to decrease the package resistance, which is the dominant portion of overall thermal resistance.
- Use of dielectric fluids opens the potential of using automatic transmission fluid (ATF) or other new driveline fluids as the coolants.
- Dielectric fluids enable cooling of the bus bars/electrical interconnects to lower capacitor and gate driver temperatures, improved cooling (single-phase heat transfer) via jet impingement and finned surfaces, elimination of expensive ceramic materials, and improved thermal performance over conventional DBC-based designs.
- Using dielectric fluids results in reduced package/conduction resistance to 33% of total thermal resistance using a relatively high convection coefficient (17,300 W/[$m^2 \cdot K$]). Dielectric fluids enable easier realization of single-side and double-side cooled packages.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The accomplishments presented are very encouraging, and the technical targets set for this year have been met and exceeded.

Reviewer 2:
The research team completed extensive simulations of their dielectric-fluid cooling approach and ran a large number of tests on the single-side cooled configuration to validate their simulation results.

Reviewer 3:
A dielectric fluid cooling system concept is developed with measured thermal performances; heat transfer coefficient of 17,300 W/($m^2 \cdot K$) at a relatively low jet velocity of 0.3 m/s, (b) 22 $mm^2 \cdot K/W$ junction-to-fluid thermal resistance (per device).

Also, it is determined that dielectric fluid cooling system leads miniaturization of power device package; achieved 120 mL total volume for conceptual 12-device module and heat exchanger; requires 4.1 L/min total flow rate; it is possible to dissipate 2.2 kW with 12 devices; junction temperature of 220°C at a heat flux of approximately 716 W/cm^2; and computed thermal resistance of 9 $cm^3 \cdot K/W$ total resistance compared to target value of 21 $cm^3 \cdot K/W$.

The project team has fabricated the finned heat spreaders. The project team also designed a cartridge heater system to simulate the 12 SiC devices with heater blocks soldered to finned heat spreaders and measured the heat exchanger (case-to-fluid) thermal resistance. The project team also fabricated a polycarbonate prototype of the dielectric-fluid heat exchanger via three-dimensional (3-D) printing (cartridge heaters and insulation not shown) and completed fabrication of the dielectric fluid loop and measured the heat exchanger (case-to-fluid) thermal resistance at various fluid flow rates and temperatures.

The reviewer commented that the project team obtained a good match between experiments and the model and explained that changing fluid temperature has minimal effect on thermal resistance but does affect pumping power. The reviewer also indicated that the project team confirmed the heat exchanger low thermal resistance values and provided confidence in model predictions.

Additionally, the project team modeled performance of Alpha 6, AC-100, and ATF at 70°C and 40°C fluid temperatures at different flow rates (1 L/min to 6 L/min). The reviewer explained that changing fluids and varying temperatures has a minor effect on thermal resistance but has a big effect on pumping power when compared at the same flow rates. The reviewer also noted that the team predicted ATF performance to be similar to Alpha 6 because they have similar properties.

The project team has compared performance of ATF cooling with existing automotive systems, determined that higher viscosities at low temperatures may not be a problem if the correct fluid is chosen and coupled with a low pressure-drop system, and developed conceptual dielectric fluid-based double-side cooled module.

Reviewer 4:
The work is systematic. A cooling system design concept was created. A prototype was fabricated and tested. Results were compared to the simulated data and a good correlation was achieved.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There are close interactions across the project team that show a strong, cohesive, and synergistic collaboration.

Reviewer 2:
It looks as the technical accomplishments shown in the presentation have mostly been developed by the Lead Organization. In this sense, it is unclear what the role was of partners John Deere and Georgia Institute of Technology (Georgia Tech).

Reviewer 3:
Project collaborators with different types and level of contributions are stated:

- John Deere (industry)—Two-phase cooling for high-packaging-density planar inverter (via a cooperative research and development agreement [CRADA]).
- Georgia Tech—Collaboration to evaluate and develop advanced cooling technologies (two-phase and inter-device cooling)
- Elementum3D (industry)—3-D-printed metal parts to evaluate new heat exchanger concepts
- ORNL—Dielectric fluid manufacturers.

Reviewer 4:
The reviewer would like to have seen a passenger vehicle OEM involved; otherwise it seems to be a well-rounded team.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future research is appropriate with the scope of the project. Given that the concept of jet impingement with dielectric fluid was proven so successful, could the project put more emphasis in the future on the optimization of the hydraulic circuit (designing the system to reduce pressure drops and opportunity to operate with different dielectric fluids), and conduct durability testing? These are critical aspects for a successful deployment of the technology.

Given that the technical targets have been addressed successfully with single-phase dielectric fluid, what would be the rationale behind exploring two-phase fluids? The risk/benefit proposition is unclear, in light of the results obtained. Perhaps this aspect could be de-emphasized, to focus more on the hydraulic system optimization based on the solution demonstrated so far.

Reviewer 2:
This reviewer looked forward to learning the team's progress of their future work on cooling modules in the double-side cooled configuration.

Reviewer 3:
The remaining challenges and barriers are right on target and the future plan addresses these issues.

Reviewer 4:
Project relevant future research topics include:

- Complete design of the double-side cooled, dielectric fluid concept
- Conduct experiments with AC-100 and ATF at various fluid temperatures and flow rates
- Collaborate with Georgia Tech to develop the advanced cooling technologies
- Fabricate a prototype of the double-side cooled concept
- Experimental demonstration/validation of the double-side dielectric fluid concept
- Evaluate the long-term reliability of the dielectric fluids
- Collaborate with Georgia Tech to develop the advanced cooling technologies.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Advanced thermal management is extremely important for successful adoption of WBG power devices that have potential to meet 2025 power-density (100 kW/L) and efficiency (greater than 97%) targets of power electronics aspired by DOE VTO.

Reviewer 2:
The cooling technologies developed in this project are key for achieving DOE Electrification's 2025 technical targets for electric drive systems.

Reviewer 3:
The project aims at defining thermal management solution that are necessary to achieve the 2025 DOE power density of 100 kW/L for power electronics.

Reviewer 4:
A key factor in achieving power density will be thermal management.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The funding level seems adequate.

Reviewer 2:
The resources allocated are sufficient so far. If the project emphasis shifts more toward packaging/design optimization and durability, more resources will have to be allocated to designing, 3-D printing, and manufacturing.

Reviewer 3:
This project has necessary resources and research funds in conjunction with result-oriented collaborations with industry and academia.

Reviewer 4:
This work is focused on cooling of switches/power modules. Cooling/thermal management of the other components will be critical in successfully achieving the project power density targets.

Presentation Number: elt212
Presentation Title: Non-Heavy Rare-Earth High-Speed Motors
Principal Investigator: Tsarafidy Raminosoa (Oak Ridge National Laboratory)

Presenter

Tsarafidy Raminosoa, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

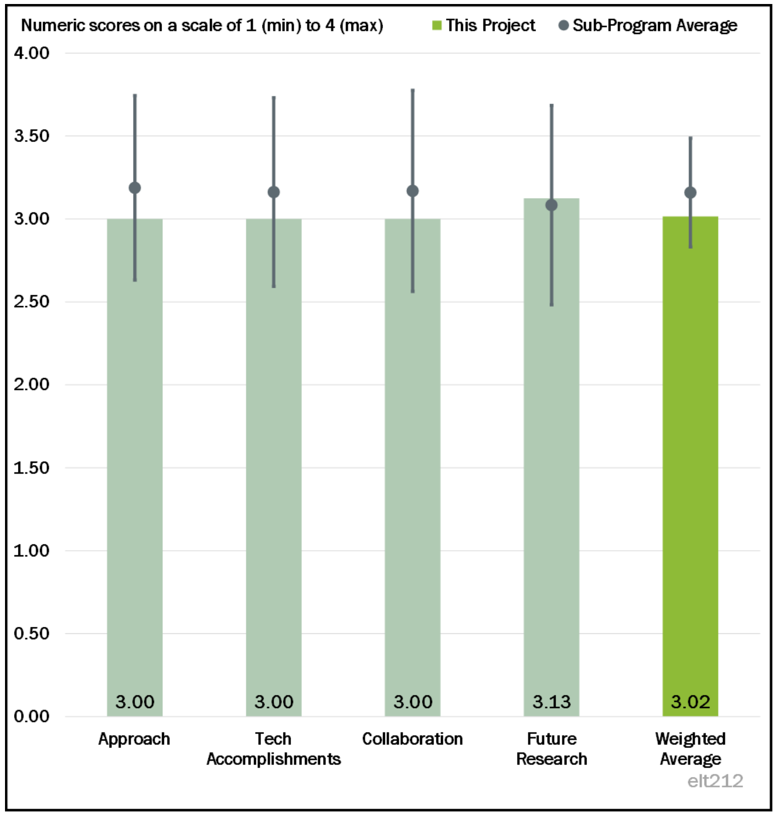

Figure 4-24 - Presentation Number: elt212 Presentation Title: Non-Heavy Rare-Earth High-Speed Motors Principal Investigator: Tsarafidy Raminosoa (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach of down-selecting a drive design from many well-known options with the constraint of avoiding dysprosium (Dy) makes sense. Working all of the individual elements (motor, inverter) is important to achieving the most optimal design.

Reviewer 2:

Approach to project is sound. Technical barriers are being addressed adequately.

Reviewer 3:

Even though there might be potential benefits of the down selected topology especially in terms of system integration and thermal management, it is not very clear that it provides a clear path to meeting the DOE targets.

Reviewer 4:

High-density, non-rare earth (RE) permanent magnet (PM) machine design is of critical importance due to the high price of these magnets and control of these materials by a single country. However, outer-rotor PM machines have their own disadvantages. Stator cooling is an issue and this can increase the copper (Cu) loss and core loss. Outer-rotor PM machines have very high centrifugal forces which can increase the high-speed mechanical loss and core loss. How do these losses affect the magnet temperature? How is the surface PM contained?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Progress is acceptable to date.

Reviewer 2:
The outer-rotor choice is interesting. Excellent progress has been made in addressing the design challenges of this configuration. One item that might need addressing is the growth of the motor volume to 3 liters (L) (if the reviewer heard that correctly) to get the inverter to fit. That seems directionally incorrect.

Reviewer 3:
Even though some mechanical stress analysis has been performed on the outer rotor design, a more detailed rotor dynamics analysis taking into consideration the bearings selection should be performed. The slides show a Halbach array, which is an expensive option for the application. Some justification for such choice should be included.

Reviewer 4:
At this stage of the project, it is very unclear how the performance indicators are met. What are the machine dimensions? What are the dimensions of the inverter? Is it single or dual inverter? Is the cooling common between the inverter and motor? How is the cost target met? Do Halbach array magnets tend to be cheaper than conventional magnets that are being currently used?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Good collaboration with other National Laboratories, especially NREL.

Reviewer 2:
Many lab teams are involved in delivering parts that must work together. The required design and data sharing seem to be in place.

Reviewer 3:
There seems to be proper collaboration and coordination among team members.

Reviewer 4:
Seems like a good collaboration between various National Laboratories. However, for this kind of project, it would be a value add if OEMs are a part of the advising team at least.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Next steps are appropriate for achieving a successful design.

Reviewer 2:
Proposed future work is well aligned and planned per the project objectives.

Reviewer 3:
Integration of the thermal management of the motor and inverter is a critical aspect of this project. How is this addressed? A plan for thermal management of motors has been outlined.

Reviewer 4:
More analysis and experimental verification are needed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is relevant and well aligned to DOE objectives in 2025.

Reviewer 2:
Increasing power density and reducing cost are major factors for EV deployment and this project is aiming to do that.

Reviewer 3:
The project supports the DOE VTO objective of widespread EV adoption. Reducing drive cost and packaging size are critical to reducing EV cost relative to the current internal combustion engine (ICE) technology.

Reviewer 4:
Directionally, the project supports the DOE objectives but there are concerns about the level of improvement expected compared to the state of the art.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources appear to be sufficient as the project is on schedule.

Reviewer 2:
Resources seem to be adequate.

Reviewer 3:
Resources are sufficient.

Reviewer 4:
The project has experienced team members to complete the project on time.

Presentation Number: elt213
Presentation Title: High-Fidelity Multiphysics Material Models for Electric Motors
Principal Investigator: Jason Pries (Oak Ridge National Laboratory)

Presenter

Jason Pries, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

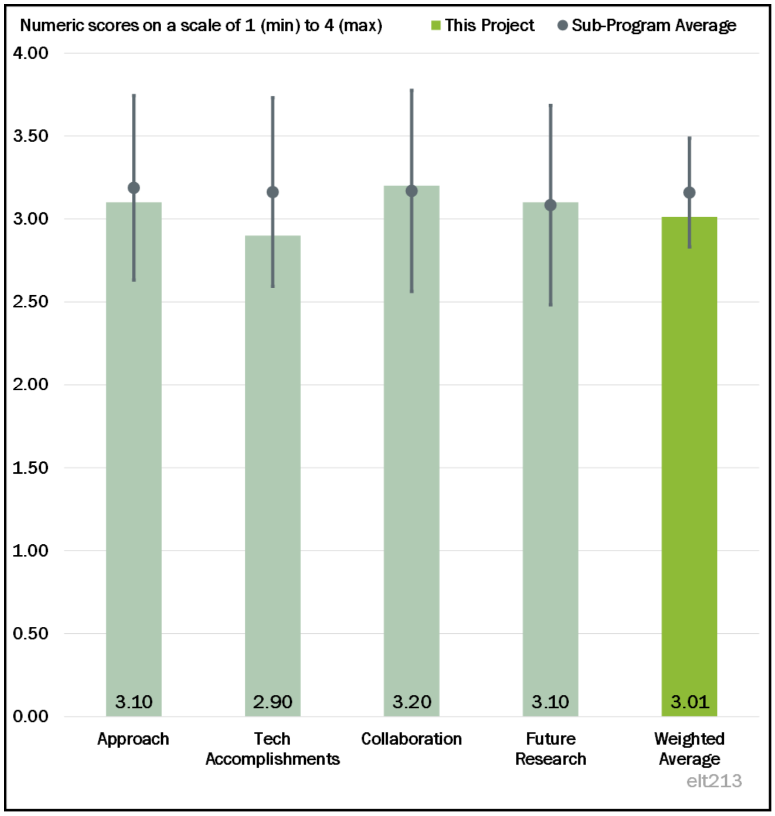

Figure 4-25 - Presentation Number: elt213 Presentation Title: High-Fidelity Multiphysics Material Models for Electric Motors Principal Investigator: Jason Pries (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The need to obtain better material models by starting with more detailed measurements of physical properties is appropriate.

Reviewer 2:

Approach to project is sound. Technical barriers are being addressed adequately.

Reviewer 3:

The approach is logical and well defined. The approach includes three steps, including testing, post processing, and analysis. Research aims to improve the science and technology for HRE-free PMs and electrical steel core losses for motor design.

Reviewer 4:

Virtual analysis of electric machines has been a topic of interest for cost reduction and performance improvement, and this project aims to do that. With core loss there is a large discrepancy between finite element analysis (FEA) simulation data and actual test data. If a factor is introduced to match the core loss between simulation and test data, this factor varies by a large factor for various operating points in the machine. Also, different FEA tools have varying levels of discrepancy. The reviewer hoped that this project will be able to close this gap and give better estimation of these losses when compared to what present knowledge.

Reviewer 5:
Even though more accurate modeling of demagnetization and high-frequency losses is generally useful in electrical machine design, it is not clear how this is going to help meet the DOE objectives, especially since it was not shown in a clear way how the proposed modeling techniques are better than what already exits or have been previously explored in literature.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Progress is acceptable to date.

Reviewer 2:
Many clever methods have been developed to effectively perform the material testing work. For example, comparisons of the actual measurements against current modeling predictions would have been useful as a gauge of the potential difficulties.

Reviewer 3:
There is some good progress made but still the differentiation compared to commercially available packages as well as other work presented in literature is not very clear. Also, the expected impact of the proposed/improved modeling techniques on the machine performance should be quantitatively presented.

Reviewer 4:
There has been some work done on characterizing the Halbach magnets. Estimating the PWM losses in the electrical steel with accurate hysteresis modeling is a major task that is yet to be performed.

Reviewer 5:
It is nice to see the development for PM test fixture and methodology for examining demagnetization curves. This is in line with the aims of the project. Project analyzed vector demagnetization requirements in Halbach outer rotor and a linear surface permanent magnet (SPM) motor. It would be nice to see other types of PM machines analyzed as well. Progress has been made to measure PWM core loss measurements.

How much will the predicted core losses be as a function of switching frequency for a given motor design? What is the trade-off between increasing the switching frequency of the inverter (higher losses for the inverter) and reducing core losses? How should the demagnetization analysis be extended for the Hallback array machine to interior permanent magnet (IPM) and SPM motors?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There has been significant collaboration between ORNL, Ames Laboratory, and NREL in this project.

Reviewer 2:
There seems to be proper collaboration and coordination among team members.

Reviewer 3:
The project requires inputs from three different labs to obtain the desired test data.

Reviewer 4:
The reviewer observed good collaboration among National Laboratories and these collaborations are well articulated and designed.

Reviewer 5:
There seems to be reasonable collaboration with other National Laboratories and teams even though there is no quantitative demonstration of the outcome of this collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Proposed future work is well aligned and planned per the project objectives.

Reviewer 2:
One of the main aspects, which is accurate estimation of PWM loss, has been captured in the milestones and deliverables. This task has been organized systematically to prove the concept in smaller levels.

Reviewer 3:
The planned work is a logical follow-up to current testing. Instead of core-loss post-processing, would it be better to integrate the improved models directly into the FEA code?

Reviewer 4:
Future work is around PWM core testing and post-processing tools for FEA simulation for FY 2020 and improving PWM losses by improving second-order reversal curves for steels and permanent magnets for FY 2021. The reviewer found out that future work is in a logical sequence and addresses the aims of the project. In addition, please see prior comments for future work.

Reviewer 5:
More quantification of impact on machine performance should be presented. Clearer comparison with the state of the art should be presented.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Electrical steel losses and PM losses and demagnetization are critical design considerations for optimizing the machine design and reducing the cost and volumetric power density of the machine. The high-frequency losses are tough to estimate, so make the losses in PM. For this reason, this project tries to close the knowledge gap in this area. It is nice to see detailed analysis and verification plans. This project is in line with DOE's goals to achieve high power density and low-cost traction motors.

Reviewer 2:
The project is relevant and well aligned with DOE objectives in 2025.

Reviewer 3:
Better materials modeling should help the goal of designing improved motors, meeting the DOE VTO performance targets.

Reviewer 4:
Virtual modeling and analysis are relevant for reducing cost and having fast turn-around for product development. This aligns very well with the DOE objectives.

Reviewer 5:
More accurate modeling is helpful, but the extent it is going to help meet the DOE targets is still not clear.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources are sufficient to meet the project milestones in a timely fashion. It is nice to see the test set-ups in picture to estimate the core and PM losses.

Reviewer 2:
Resources appear sufficient to execute the testing required.

Reviewer 3:
Resources seem to be adequate.

Reviewer 4:
Resources are sufficient.

Reviewer 5:
The team is very knowledgeable and can complete the project in time.

Presentation Number: elt214
Presentation Title: Electric Motor Thermal Management
Principal Investigator: Kevin Bennion (National Renewable Energy Laboratory)

Presenter

Kevin Bennion, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

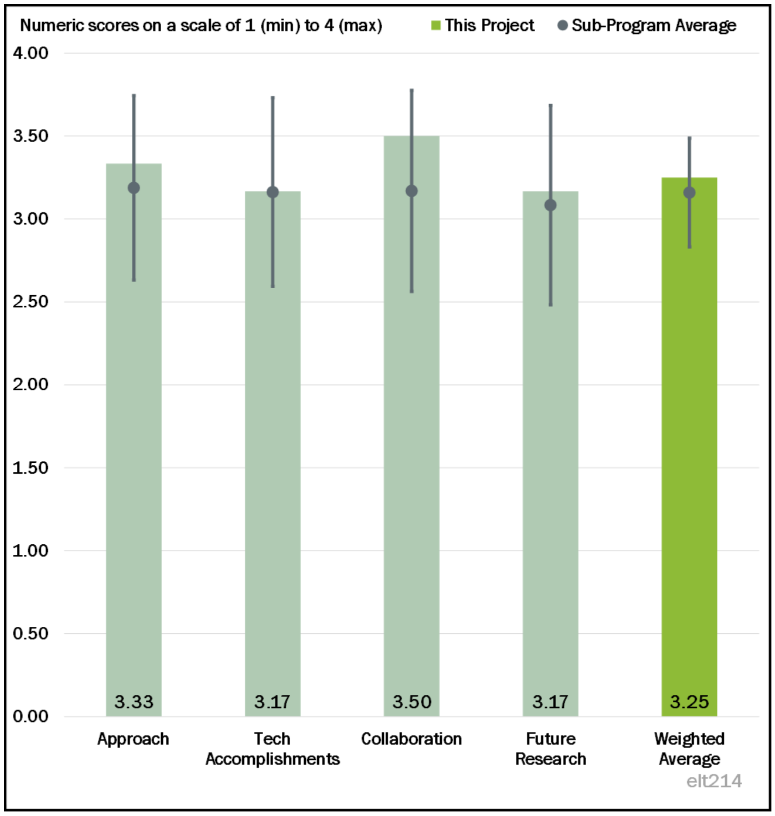

Figure 4-26 - Presentation Number: elt214 Presentation Title: Electric Motor Thermal Management Principal Investigator: Kevin Bennion (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project is about the material and interfaces of thermal and mechanical characterization and thermal analysis. The approach includes material and thermal characterization, including slot liners. Collaboration with SNL is carried out. Collaboration with Georgia Tech and ORNL for heat transformer technologies and advanced motor thermal analysis, respectively, are carried out.

The reviewer found that the aims of the project are timely, needed, and well defined. The project has a strong collaboration with ORNL, Georgia Tech, and SNL.

Reviewer 2:

The project appears to be well organized to provide the thermal management solutions for the motor being designed. The materials characterization is an important contribution to the thermal modeling accuracy.

Reviewer 3:

In general, thermal management is critical in terms of increasing the machine power density, and characterizing materials and interfaces is very helpful, but it is not clear that there are significant new technologies or approaches proposed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Significant progress has been achieved by developing an excellent approach for machine thermal modeling and analysis. Various cooling techniques have been evaluated, including the stator cavity cooling. Detailed analyses have been performed for stator cavity cooling. Other multiple approaches for stator cooling have also been well studied, including in-slot cooling for stator and stator teeth and high-performance potting compound.

The reviewer found that the project had made excellent progress and accomplished the goals of the project for this budget period.

Reviewer 2:
Progress is good. Are the six operating points used for the preliminary thermal analysis representative of what the motor would see in operation?

Reviewer 3:
Reasonable progress is made, but the novelty of the work done especially in comparison to the state of the art needs to be emphasized and clarified.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Laboratory and university collaborations appear to be working very well to achieve the test and analysis results.

Reviewer 2:
There is good collaboration between multiple team members.

Reviewer 3:
The project has significant collaboration with SNL, ORNL, and Georgia Tech. The reviewer observed excellent teamwork in the project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Next steps are appropriate in extending the work underway.

Reviewer 2:
More quantitative assessment of how the proposed research can affect the motor power density should be performed and presented.

Reviewer 3:
The project focuses on slot liner and interface contact resistance and developing system-level thermal validation and testing.

It would be nice if there were some articulation about the investigation of other types of cooling topologies and how collaboration will be achieved with other National Laboratories in future planning. What are the results and comparisons among different types of cooling topologies, and how does that compare to today's technology and best practices in the auto industry?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Thermal analyses provided by this project are an important contribution to accomplishing the DOE VTO motor specification targets.

Reviewer 2:
Research support the goal of minimization of electric machines for traction applications.

Reviewer 3:
Thermal management is critical but novelty should be clarified.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer found the overall project performance to be outstanding. Excellent collaboration, planning, and execution of project goals and milestones have been achieved.

Reviewer 2:
Resources appear to be sufficient.

Reviewer 3:
Resources are sufficient.

Presentation Number: elt215
Presentation Title: Permanent Magnets without Critical Rare Earths to Enable Electric Drive Motors with Exceptional Power Density
Principal Investigator: Iver Anderson (Ames Laboratory)

Presenter

Iver Anderson, Ames Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers indicated that the resources were sufficient, 17% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

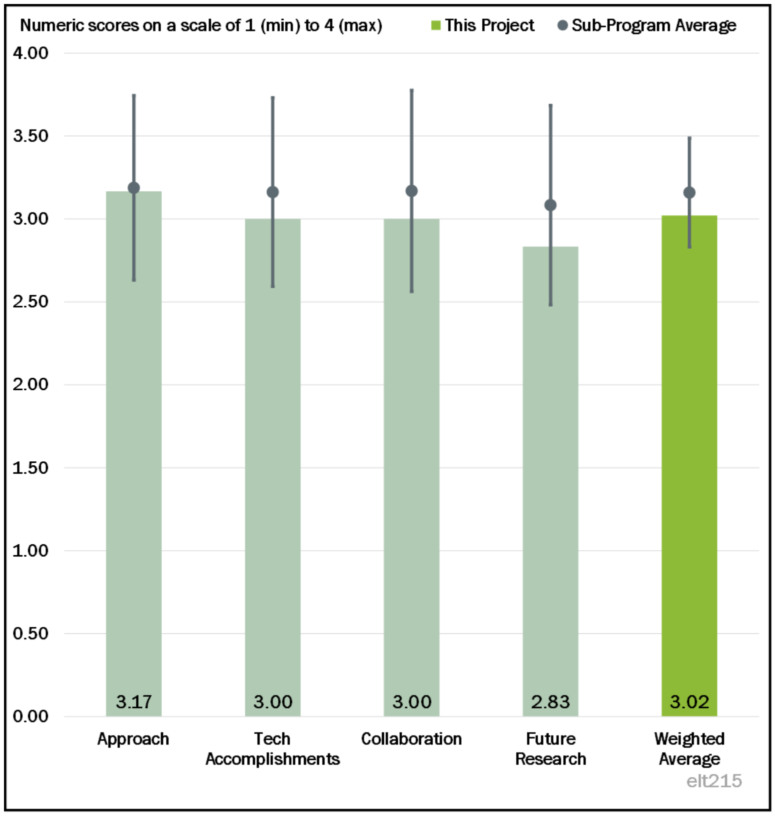

Figure 4-27 - Presentation Number: elt215 Presentation Title: Permanent Magnets without Critical Rare Earths to Enable Electric Drive Motors with Exceptional Power Density Principal Investigator: Iver Anderson (Ames Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This is fundamental work that needs to be done if HRE-free magnets are to become more effective.

Reviewer 2:

The project is about magnetic material development and processes for electrical steel loss and PM modeling. The project focuses on reduction of HRE metals and aims to improve the motor power density.

The reviewer observed that the project is well defined and aims to fill the knowledge gap in the materials area as applied to motors.

Reviewer 3:

The approach to project is sound. Technical barriers are being addressed adequately.

Reviewer 4:

The project is systematically exploring the barriers to achieving higher performance with lower RE content in sintered NdFeB magnets. The project has chosen to focus on controlling the grain size distribution as well as adjusting the composition of intergranular phases, which is a reasonable approach. The decision to prioritize the ultra-fine-grain approach over the gradient-magnet approach was appropriate, given the relative rate of progress between the two tasks.

Reviewer 5:
Eliminating Dy is very useful, but it is not clear that the proposed approach will lead to significant improvement compared to the state of the art in order to meet DOE's very demanding targets.

Reviewer 6:
Producing PMs having high energy density without the use of HRE materials is an important topic. This will reduce dependence on importing these HRE materials. Task 2.7 aims at developing high coercivity PMs at high temperature; it does not show how this coercivity compares with state-of-the-art PMs with HRE or reduced HRE materials. Defining the goals is one aspect but how it compares to the state-of-the-art PM materials is important. Also, it does not clearly compare the B values and the energy density values at different magnet temperatures. Without this information, it will be difficult to adopt these materials in real traction applications.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project has made noteworthy performance in exceeding the coercivity of commercially available NdFeb magnets using the ultra-fine-grained processing methods. The data generated while producing these samples are quite valuable and will accelerate future increases in performance.

Reviewer 2:
The approach is centered around processing ultra-fine grain size RE-PM without HRE. The project mainly aims to down-select exceptional powder production methods and validate the mechanism of enhancing coercivity through the fine-grain approach.

Project has great progress to achieve the milestones of the project.

Reviewer 3:
Progress is acceptable to date.

Reviewer 4:
There is a lot of good work being done but it is hard to judge the effectiveness of the results without knowing the targeted improvement. Researchers also note that the processes used could be more challenging to implement. Is there a cost/benefit target?

Reviewer 5:
25% improvement in coercivity is significant, but the impact on machine performance is not clear.

Reviewer 6:
There has been significant progress in the industry toward reducing/completely eliminating HRE materials while still maintaining high energy density. This project takes a different approach toward achieving the same goal. However, it does not compare how this material performs when compared to the state-of-the-art PM materials currently used in traction application. Comparison of magnetic flux (B) –magnetic field strength (H) characteristics at various temperatures (20°C, 100°C, 150°C, 180°C, and 200°C is needed). Thermal coefficient of remanence (Br) and coercivity (H_{cj}), and coefficient of thermal expansion of these materials should be compared to the state of the art.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Experts across several labs are engaged to produce the best outcome.

Reviewer 2:
There seems to be proper collaboration and coordination among team members.

Reviewer 3:
There seems to be reasonable collaboration with other National Laboratories.

Reviewer 4:
The project has collaboration with ORNL, NREL, and SNL. Collaboration strategy for motor design, thermal and mechanical properties of newly developed magnetic materials, and coordination with universities are well defined. The laboratories are complementary to each other's contributions and have a balanced shared amount of work.

Reviewer 5:
ORNL appears to have contributed expertise in motor performance simulation. The specific contributions of NREL and SNL were not called out in the presentation.

Reviewer 6:
The project team has strong collaboration with National Laboratories. However, the applicability of the materials developed and the commercialization aspects can be better addressed by the OEMs and magnet manufacturers (example, Arnold magnetics). Without the OEMs and magnet suppliers, it is difficult to benchmark the performance and cost, which are critical for adoptability of these materials in real applications.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Next steps are appropriate; from the wording, the jet-milling work seems to be contingent on external actions.

Reviewer 2:
Proposed future work is well aligned and planned, per the project objectives.

Reviewer 3:
The proposed future focus on multi-jet milling and oxygen-free powder handling is a valid approach to solving the remaining technical problem. Given the lack of domestic availability of jet-milling equipment, alternate approaches for size refinement should be identified, if they exist.

Reviewer 4:
Future research is well defined and includes a multi-jet milling system to perform critical experiments, development of additive composition and quantity for HRE-free, RE-PM alloy powder, and validate the hypothesis that mechanical properties improve for the ultrafine-grain magnet. Future research is in line with the aims of reducing PM cost and the HRE element and increase the power density of the traction motor.

The reviewer questioned what are the predicted losses and efficiency comparison with proposed magnets and existing magnets on a motor design?

Reviewer 5:
Impact of achieved properties on machine performance should be evaluated, and more focus on scalability is needed.

Reviewer 6:
The presentation claims low-power density with non-RE PM machines. However, it is not clear how the project has addressed this barrier by showing experimental comparison between the HRE free materials developed in this project and the state-of-the-art PMs to achieve 50 kW/l at $3.30/kW.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Work is critical to maximizing motor performance without resorting to HRE magnets. This goal is central to meeting DOE VTO drive unit metrics.

Reviewer 2:
The project is relevant and well aligned with DOE objectives in 2025.

Reviewer 3:
Yes, this project supports the overall DOE objectives of enabling higher power density motors that minimize the use of critical raw materials.

Reviewer 4:
Eliminating HRE material is very relevant in terms of cost reduction and sustainability.

Reviewer 5:
The DOE goals require to increase power density and lowering the cost of the traction motor. HRE metals are costly. Hence, developing new magnets and processes are one of the critical elements to reduce the cost. Also, this work can improve high efficiency, which yields to reduce cooling. If cooling is reduced, there is an extra reduction of cost in the cooling system.

Reviewer 6:
Even though the DOE objective is supported, the performance metrics have not been showcased as of now in this project.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources seem to be adequate.

Reviewer 2:
Resources are sufficient.

Reviewer 3:
Resources are sufficient to carry out the work.

Reviewer 4:
The resources of the team appear to be sufficient. However, the lack of domestic availability of multi-jet milling equipment poses a risk if the Consortium cannot procure one in a timely fashion.

Reviewer 5:
Resources seem sufficient, but the comments about the jet-milling work under proposed future research leaves some doubt.

Reviewer 6:
Without collaboration from OEMs and magnet manufacturers, it is not an easy task to achieve the deliverables mentioned in this project.

Presentation Number: elt216
Presentation Title: Isotropic, Bottom-Up Soft Magnetic Composites for Rotating Machines
Principal Investigator: Todd Monson (Sandia National Laboratories)

Presenter

Todd Monson, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

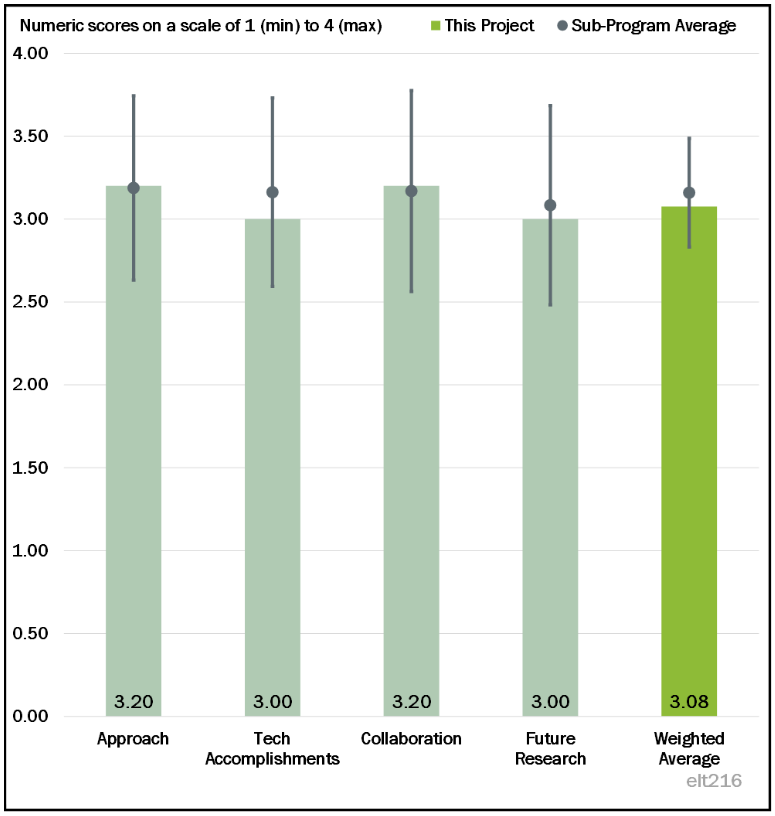

Figure 4-28 - Presentation Number: elt216 Presentation Title: Isotropic, Bottom-Up Soft Magnetic Composites for Rotating Machines Principal Investigator: Todd Monson (Sandia National Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project aims to develop improved soft magnetics to achieve the DOE's cost and power targets. These soft magnetic materials are proposed to replace steel in PM motors. The project seeks to demonstrate 65 vol.% loading iron nitride (Fe_4N)/epoxy composite and 80 vol.% loading of Fe_4N. The reviewer found that the technical content of the presentation was excellent on the material science level. Milestones, aims, and approach are laid out.

Reviewer 2:

The project goals are compatible with the challenge of maximizing performance of non-HRE magnet motors. Engineering materials to maximize performance is a key task.

Reviewer 3:

Approach to project is sound. Technical barriers are being addressed adequately.

Reviewer 4:

The project addresses some, but not all, of the technical barriers involved in evaluating a new soft magnetic material for use in electrical machines. In particular, more focus should be given to benchmarking the Fe_4N composite performance to the materials conventionally used in motors, including Si steel and soft-magnetic-composites. Furthermore, the metallurgical characteristics of the γ-Fe_4N compound should be addressed as well. In particular, this is not a thermodynamically stable compound at room temperature and pressure and will decompose and off-gas nitrogen at elevated temperature. This may influence the lifetime of the soft magnetics components. The rate of nitrogen evolution at the maximum operating temperature should be assessed. The stability of the compound under the hot-pressing conditions should also be evaluated.

Reviewer 5:
Some analysis showing the expected improvement in performance with the novel proposed material versus Si steel laminations should be performed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
There has been very good progress on material fabrication. It would be good to list targets to be met. For example, the reviewer appreciated the permeability improvements shown on Slide 14 but is there an expected limit?

Reviewer 2:
Progress is acceptable to date.

Reviewer 3:
There is good progress made but comparison to the state of the art is needed.

Reviewer 4:
The project has made good progress to meeting the goal of evaluating Fe_4N's performance.

Reviewer 5:
Fabrication of samples for thermal and mechanical testing and experimental set-ups are planned and shown. An epoxy sample has been produced. Mechanical testing has been prepared.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project has strong collaboration ties with Purdue University, Illinois Institute of Technology, ORNL, Ames Laboratory, and NREL. It is nice to see that there is a mutual connection and work share among different laboratories and academic institutions.

Reviewer 2:
The team is fairly large (six members), but the roles are well defined and well coordinated.

Reviewer 3:
The partners bring needed and complementary areas of expertise to the project.

Reviewer 4:
There seems to be proper collaboration and coordination among team members.

Reviewer 5:
There seems to be some level of collaboration, but it needs to be improved, especially in terms of evaluating the impact of the proposed material on the machine performance.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Next steps are logical.

Reviewer 2:
Proposed future work is well aligned and planned per the project objectives.

Reviewer 3:
Future research includes soft magnetic material as applied to motor design and evaluates its saturation and eddy-current losses. Plans include improving the chemistry and demonstrating the new composite material in a motor design.

Reviewer 4:
The proposed future work will provide sufficient data to evaluate the performance of the Fe4N material in new motor designs. To be most useful, the new material's properties and estimated manufacturing cost should be compared to existing soft magnetic materials.

Reviewer 5:
More quantification of machine performance is needed.

It would be nice to include more details about the motor design in the presentation and future work. What kind of motor, what are the implementation challenges, losses, efficiency, etc.?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Maximizing/optimizing motor component material properties is necessary to achieve the DOE VTO motor performance goals/targets.

Reviewer 2:
The project is relevant and well aligned with DOE objectives in 2025.

Reviewer 3:
Yes, the project addressed the DOE goal of enabling higher performance electric motors with reduced critical material content.

Reviewer 4:
Yes, it does meet the overall DOE objectives for cost and power target because soft magnetic materials can be made more cheaply than laminated steels. In addition, there will be fewer losses in the core material and cost savings in the cooling system.

The reviewer questioned what the loss calculation and efficiency comparison are of the proposed soft magnetic component material compared to lamination-steel based design. If details are provided in the next budget period, that would be great.

Reviewer 5:
The project is relevant especially if more quantitative analysis of the machine performance is presented.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project is on schedule with given resources.

Reviewer 2:
Resources seem to be adequate.

Reviewer 3:
Resources are sufficient.

Reviewer 4:
The resources of the project are sufficient to meet the stated milestones.

Reviewer 5:
Yes, resources are adequate, and testing for experimental set-up is shown in the presentation.

Presentation Number: elt217
Presentation Title: Integrated/Traction Drive Thermal Management
Principal Investigator: Bidzina Kekelia (National Renewable Energy Laboratory)

Presenter

Bidzina Kekelia, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

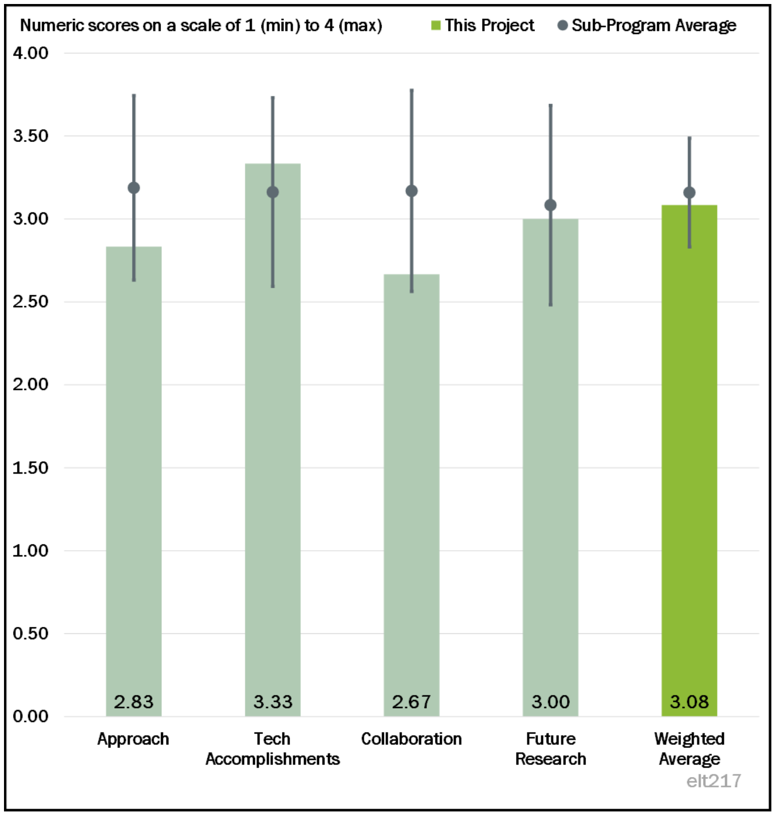

Figure 4-29 - Presentation Number: elt217 Presentation Title: Integrated/Traction Drive Thermal Management Principal Investigator: Bidzina Kekelia (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The computational fluid dynamics (CFD) study of various jet types (circular, fan, off-center fan, oblique fan, etc.) and their characteristics is a sound approach to developing guidelines for direct cooling in electrified propulsion system design. Also, the planned future exploration and experimentation with different fluid types and characteristics will be useful in this regard.

Reviewer 2:

The approach makes sense. The reviewer would like to have seen some planning and provision for a practical implementation of jet impingement cooling techniques. The jet impingement devices depicted look large compared to the devices they are cooling.

Reviewer 3:

This is a very important project, but it does not appear to be advanced enough (as a second-year reviewer of this project).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

There is excellent technical progress in demonstrating the viability and effectiveness of the jet-impingement cooling technique.

Reviewer 2:
Technical accomplishments (CFD results) are strong. Steady progress is being made toward targets.

Reviewer 3:
Some progress was made.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
John Deere is part of the project team, but their contribution to the project is not well explained.

Reviewer 2:
Collaboration is not very evident.

Reviewer 3:
The second project partner (John Deere) is yet to show their contributions, as their tasks do not start until later this year. The team is well equipped.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
More quantification of the impact of the new materials on machine performance has to be performed. The impact of higher temperatures on efficiency has to be quantified. The proposed high-speed has to be proven to be practical.

Reviewer 2:
The plan to meet the project objectives is not well defined. The plan to develop the electromagnetic, thermal, and mechanical design of the motor is not presented. Go/no-go decisions points are not identified. The risks and mitigation plans are not identified. The scaled-up manufacturing capacity for the new materials is not demonstrated.

Reviewer 3:
Some of the concerns below have to be addressed at some stage of the project. This will help in realizing the proposed technology and also to check the go/no-go decision.

- Regarding the mechanical strength of the rotor and stator material, what is the tensile strength and yield strength of the SMC used in the rotor and stator?
- With respect to the core loss versus frequency, SMCs might have better core loss at high frequency. However, how do the B-H characteristics and the core loss versus frequency compare for the standard electrical steel used in traction application versus SMC material used in this project? If tB of the SMC material is relatively lower when compared to the electrical steel, then more current is needed to get the same torque.
- How does the resistance vary with temperature and what is the Cu loss at various regions of the machine? The high-temperature operation is going to create very high losses. How is this heat (due to the loss) going to be rejected? If there is an enhanced cooling system, then what is the cost of that cooling system? If the cooling system is going to be lot costlier, it can go against the DOE targets.
- What kind of inverter is planned in this project? Is it WBG-based? If so, what is the switching frequency? If the switching frequency is very high, how are the dv/dt and EMI issues addressed in this project?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Novel materials are helpful, but there are concerns about practicality.

Reviewer 2:
Yes, this project meets the DOE objectives for high-speed motors operating at high temperatures.

Reviewer 3:
High-speed machines can increase the power density while reducing the volume and reducing the cost. All of these are important targets that are well aligned with what DOE is seeking.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources are sufficient.

Reviewer 2:
The team has experienced personnel to deliver the tasks outlined in this project.

Reviewer 3:
The scaled-up manufacturing capacity for the new materials is not identified. The testing capability and performance metrics that need to be met are not specified.

Presentation Number: elt218
Presentation Title: Advanced Power Electronics Designs–Reliability and Prognostics
Principal Investigator: Doug DeVoto (National Renewable Energy Laboratory)

Presenter

Doug DeVoto, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 33% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

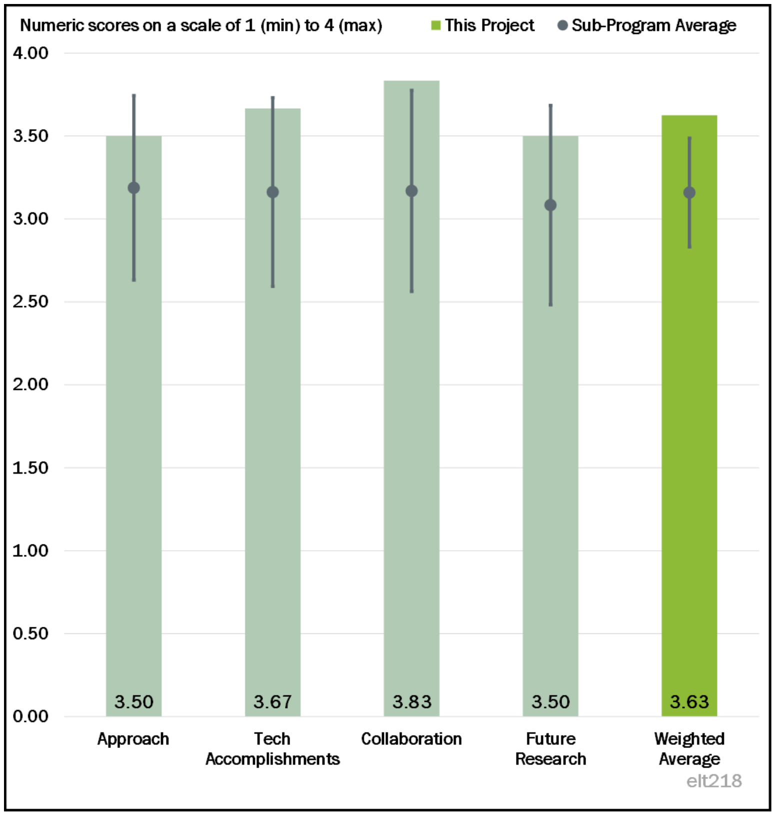

Figure 4-30 - Presentation Number: elt218 Presentation Title: Advanced Power Electronics Designs–Reliability and Prognostics Principal Investigator: Doug DeVoto (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The quilt packaging via a chip to chip edge to the interconnect is novel, albeit risky, while the ODBC substrate as a replacement to ceramic substrate is promising. Both approaches are effective to tackle the barriers of thermal and reliability of packing power electronics.

Reviewer 2:

The PI has identified that new WBG package designs must address thermal and reliability concerns and be evaluated under accelerated conditions that approximate real-world conditions. This shows the PI has plan for commercialization of developed technology. Partnership with ORNL, Indiana Integrated Circuits (IIC), and DuPont is addressing supply chain issues of expert advice and material supply in development of quilt packaging of WBG devices via chip-to-chip interconnect technology for packages that are suitable for wire bond-less and double-sided cooling.

Reviewer 3:

The work is focusing on critical issues and new technologies that are needed. The reviewer would like to have seen this project take a broader look at interconnects, insulators, and conductors for power electronics.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Thermal parametric analysis of quilt package and thermomechanical analysis of device-attach solder layer are good achievements for the year.

Reviewer 2:
This 4-year project has made quite a great progress, and the PI has the following technical accomplishments:

- Completed thermal parametric analysis of quilt package devices mounted onto ODBC substrates carrying device spacing, ODBC layers and their thicknesses, metallization thickness and heat transfer coefficient
- Found that substrate designs can maintain device temperatures under 160°C
- Completed thermomechanical analysis of device-attach solder layer
- Delivered first round of quilt-packaged devices from IIC
- Laid out sample characterization plan under accelerated thermal and vibration conditions.

Reviewer 3:
A broad range of variants were assessed for both the substrate and chip interconnect.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaborations with IIC and DuPont are critical to the project.

Reviewer 2:
The project team is appropriate and needful collaboration is underway in successful execution for project tasks targeted for milestones.

Reviewer 3:
The reviewer would like to see more involvement with vehicle OEMs.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future work is appropriate.

Reviewer 2:
Full module assembly and evaluation are critical to success.

Reviewer 3:
Future work is sufficiently stated.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
A reliable and compact WBG packaging is important to deliver full potential of WBG semiconductors.

Reviewer 2:
This work will play a significant role in the next generation of power electronics.

Reviewer 3:
Sending out developed packages to industry with request to test these packages for a targeted application could accelerate commercialization of underlining technology.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This work should be expanded to investigate other potential interconnects and substrates.

Reviewer 2:
The reviewer indicated that $350,000 for 2 years is reasonable.

Reviewer 3:
Appropriate resources are there in the project.

Presentation Number: elt219
Presentation Title: Power Electronics Materials and Bonded Interfaces–Reliability and Lifetime
Principal Investigator: Paul Paret (National Renewable Energy Laboratory)

Presenter

Paul Paret, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 33% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

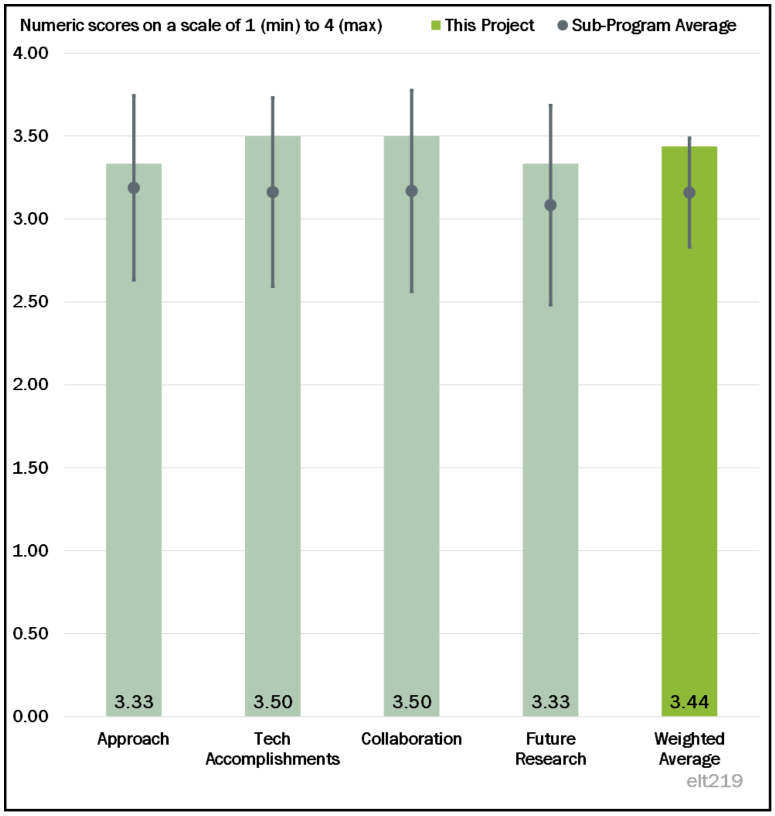

Figure 4-31 - Presentation Number: elt219 Presentation Title: Power Electronics Materials and Bonded Interfaces–Reliability and Lifetime Principal Investigator: Paul Paret (National Renewable Energy Laboratory)

Question 1: A. Approach to performing the work - the degree to which technical barriers are addressed, the project is well-designed and feasible.

Reviewer 1:

The approach, both experimental and modeling, is effective in terms of evaluating the reliability of the bonded interface materials for high-temperature power electronic applications.

Reviewer 2:

The experimental and modeling approach is quite relevant. Samples were developed, tested and characterized to prove that soldering method to attach two materials (Cu and Invar) leads to a far improved bind compared to low-pressure sintering.

Reviewer 3:

Both experimental and analysis effort will help with accuracy of the findings. The reviewer had no concern, though. When determining the performance of a joint, how does one know if it were the result of the material or how the samples were produced?

Question 2: B. Technical Accomplishments and Progress toward overall project - the degree to which progress has been made, measured against performance indicators.

Reviewer 1:

Samples with different and varying bonding diameter were fabricated, tested, and data plotted for comparison. Mechanical characterization and reliability evaluation of fabricated test samples have been carried out, and the failure mechanism is discussed in the project report. As per the PI, project milestones and tasks for future milestones are on track.

Reviewer 2:
The work and the results on sintered nano-silver are interesting. This is somewhat expected, but it is still nice to see the actual results. The results on transient liquid phase copper (Cu)/aluminum (Al) bonds are okay the reviewer looked forward to seeing the nickel-coated Cu results.

Reviewer 3:
Multiple samples were produced and evaluated.

Question 3: C. Collaboration and Coordination Across Project Team

Reviewer 1:
The project lead organization, NREL, is collaborating with Virginia Polytechnic Institute and State University (Professor G. Q. Lu), Georgia Tech (Professor Samuel Graham), ORNL, and Ames Laboratory. This collaborative teamwork is bearing excellent results.

Reviewer 2:
The collaboration with ORNL and Ames Laboratory is minimal, but with Virginia Tech and Georgia Tech, the collaboration is extensive. All the samples are from them.

Reviewer 3:
The project needs industry involvement, such as a power module supplier or a vehicle OEM that is heavily involved in the design and build of its power electronics. Also, equipment and manufacturing groups should be brought into the project.

Question 4: D. Proposed Future Research - the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The quality of joints is heavily dependent on the manufacturing process and before performing characterization testing. The reviewer needed to have confidence that the test accurately reflects reality.

Reviewer 2:
Future research includes very relevant tasks, such as: investigate the effect of sample stiffness on reliability; develop a preliminary microstructural crack propagation model; conduct mechanical characterization of Cu/Al alloy at different strain rates and temperatures; synthesize Cu/Al alloy samples with high bond quality (less than 5% initial void fraction); conduct accelerated thermal cycling of Cu/Al bond samples under different temperature profiles; expand the microstructural crack propagation model to include physics at lower length and time scales and establish microstructure-property relationships to accelerate novel high-temperature material development; and investigate the reliability and failure mechanisms of alternate high-temperature materials, such as sintered Cu and Cu-tin (Sn) transient alloys.

Reviewer 3:
The proposed research is reasonable. The most interesting and impactful research is the synthesis of Cu/Al alloy samples with high bond quality. The failure mechanism study is somewhat phenomenological; it will be more impactful if it can be linked to materials physical properties.

Question 5: E. Relevance - Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This work will significantly contribute to power density and cost.

Reviewer 2:
Reliable bonding is critical for all power electronics.

Reviewer 3:
Advanced materials and manufacturing processes for WBG power devices is a relevant and timely topic that the project PI is working in a collaborative research environment.

Question 6: F. Resources - How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The funding level is sufficient.

Reviewer 2:
The project has all necessary resources.

Reviewer 3:
Work needs to be broadened to have manufacturing and equipment providers involved.

Presentation Number: elt221
Presentation Title: Integrated Electric Drive System
Principal Investigator: Shajjad Chowdhury (Oak Ridge National Laboratory)

Presenter

Shajjad Chowdhury, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 33% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

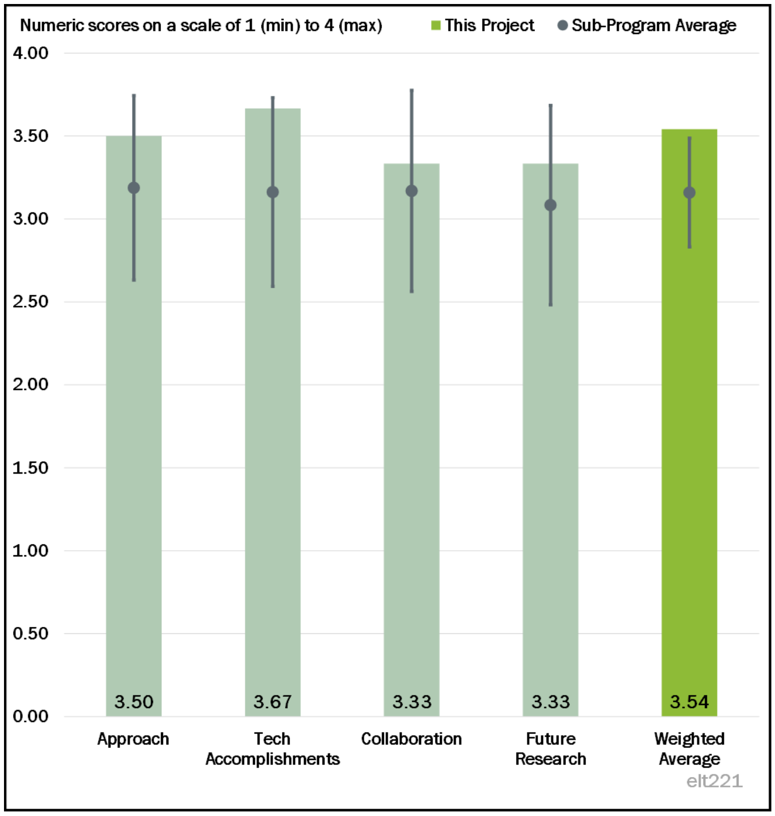

Figure 4-32 - Presentation Number: elt221 Presentation Title: Integrated Electric Drive System Principal Investigator: Shajjad Chowdhury (Oak Ridge National Laboratory)

Question 1: A. Approach to performing the work - the degree to which technical barriers are addressed, the project is well-designed and feasible.

Reviewer 1:
This is excellent and very relevant work.

Reviewer 2:
The project looks at the appropriate components to optimize and/or redesign to achieve the target inverter power density.

Reviewer 3:
The approach used to identify and select the candidate design (external rotor with inverter inside the stator hollow) is sound. The approach used to design and select the capacitor and heat sink (genetic algorithm) for the power module is also sound.

Question 2: B. Technical Accomplishments and Progress toward overall project - the degree to which progress has been made, measured against performance indicators.

Reviewer 1:
The reviewer said there is excellent work on evaluation of new capacitor technology. This is exactly what this type of project should be doing.

Reviewer 2:
There is excellent progress on capacitor selection, circular topology selection, and compact heat sink design.

Reviewer 3:
The project seems to be on track.

Question 3: C. Collaboration and Coordination Across Project Team

Reviewer 1:
There is very good collaboration.

Reviewer 2:
The reviewer noted good collaboration with NREL (thermal), SNL (WBG devices) and Ames Laboratory (new magnetic material) to design/prototype an optimal propulsion system.

Reviewer 3:
There is good collaboration. Would industry or university partners help the cause?

Question 4: D. Proposed Future Research - the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The next steps are appropriate for this work.

Reviewer 2:
The team seems to know what needs to be done.

Reviewer 3:
Assessing the impact of stator heat on the inverter components will be a critical step toward successfully executing this concept architecture. Capacitor packaging will also be a key next step. So future plans as stated are sound.

Question 5: E. Relevance - Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The inverter design is a key contribution to reaching the DOE VTO electric drive performance targets.

Reviewer 2:
This project is a key enabler for DOE's stated goal of a compact, efficient, cost-effective 33 kW/L drive system.

Reviewer 3:
This is very relevant research.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project needs more funding, according to the reviewer.

Reviewer 2:
Resources appear sufficient as the project work is on schedule.

Reviewer 3:
The allocated funds of $400,000 for 2020 are adequate for achieving the project goals.

Presentation Number: elt222
Presentation Title: High-Reliability Ceramic Capacitors to Enable Extreme Power Density Improvements
Principal Investigator: Jack Flicker (Sandia National Laboratories)

Presenter

Jack Flicker, Sandia National Laboratories

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 33% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

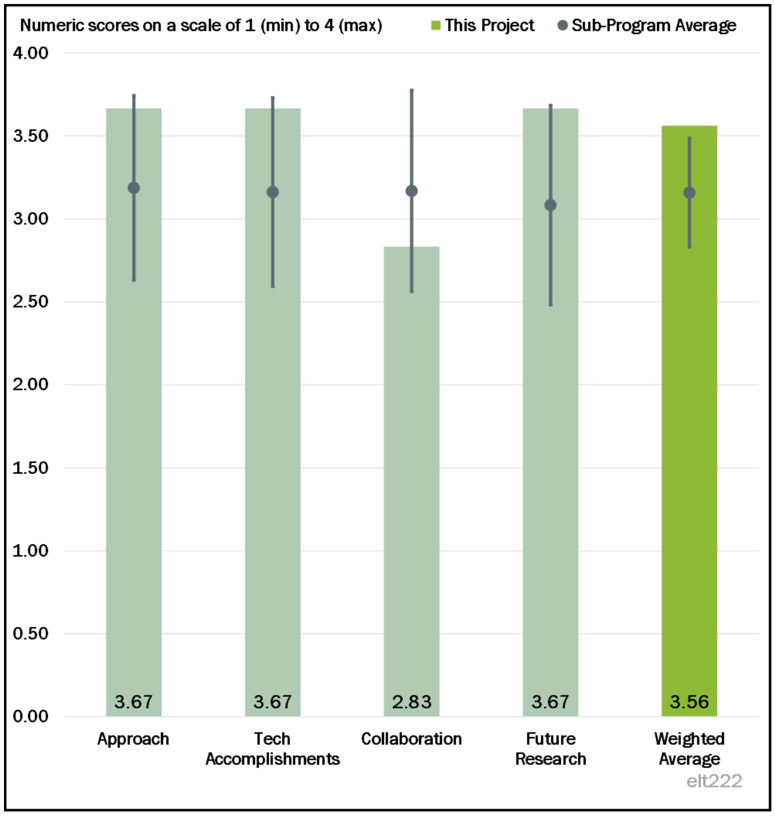

Figure 4-33 - Presentation Number: elt222 Presentation Title: High-Reliability Ceramic Capacitors to Enable Extreme Power Density Improvements Principal Investigator: Jack Flicker (Sandia National Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Oxygen vacancy migration is the main cause for failure at high voltage and high temperature. So, the total time the capacitor is subject to voltage above a critical value dictates its failure. For DC voltage, this is the total test time; for AC voltage, it is a small fraction of the test time. Slide 10 could be misunderstood as the AC field extended lifetime. To check the idea on Slide 9, a capacitor can be tested under DC voltage for 2 hours, then reverse polarity for another 2 hours, then repeat this procedure. The group might have been thinking of this already as the PI mentioned on Slide 16 “Evaluating long term voltage reverse bias healing step when vehicle is not in operation.”

Reviewer 2:

The project PI made the case that a ceramic capacitor could lead to increased power density of the traction inverter and could support meeting the DOE VTO power density target (33 kW/L) for electric drive systems. However, the highly accelerated lifetime testing (HALT) needs to be carried to understand failure caused by the build-up of oxygen vacancies at electrode surfaces and followed by devising mechanism to apply bi-polar voltage bias to clear-up oxygen vacancies at electrode surfaces. Therefore, this reviewer opined that the problem is well thought-out and a solution can be engineered by testing and experimentation of a large number of samples to capture failures caused by infant mortality and early wear-out mechanism.

Reviewer 3:
This project has an outstanding outline of objectives and properly placed proof of point experiments. The project is 30% complete and shows excellent demonstration of the technology and its ability to elongate the lifetime of capacitors.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Excellent progress has been made. The data shown on Slide 10 are convincing and exciting.

Reviewer 2:
The HALT method is developed including dedicated test for large number (40) of samples. Capacitors tested for degradation observation at DC bias and bipolar switching of 0.1, 2.5 hertz (Hz), and 10 Hz. It is found that 10 Hz AC bias testing has raised life of the capacitor by a factor of 6 (100 hours) compared to DC bias testing at 10 times the voltage and above 125°C operating temperature. A mathematical model of lifetime estimation is under development.

Reviewer 3:
The project is 30% complete and gives a good demonstration of the technology as intended at this time in the project. The reviewer would like to encourage the researchers to include additional capacitors in their testing going forward.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration with NREL and ORNL is briefly mentioned.

Reviewer 2:
ORNL is being engaged to seek support in developing a circuit for bi-polar bias and implementing bi-polar bias circuit in a DC bus of a traction drive system, yet keeping the cost of drive system unchanged. The NREL team is supporting development of novel high-density integration and thermal management of ceramic capacitors and power modules.

Reviewer 3:
The project has not demonstrated much collaboration up to this time. A clear role for organizations mentioned as collaborators should be provided.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed research on more experiments on bipolar switching and evaluating switching schemes are important.

Reviewer 2:

The project plan in addition to X7R ceramic capacitor under study, plans to include KC-Link and CeraLink DC capacitors as these may have different activation energy and could vary significantly from X7R. Perform further experiments on bipolar switching. Evaluate bipolar switching scheme compatibility with drive train technologies.

Reviewer 3:
The project is at a critical stage and next steps and details related to a large study on failure analysis data are really outstanding. Including additional capacitors for large scale HALT studies would be very useful.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project will help meet DOE energy density targets as overall goal.

Reviewer 2:
A high-temperature ceramic capacitor is important for power electronics. Service life of ceramic capacitor has been a barrier. By simply implementing a bipolar switching scheme, one can 5x the service life is an impressive achievement. It will impact the future EV power electronic design in a very positive way.

Reviewer 3:
This is a very timely and relevant topic to meet the following DOE targets, goals and objective stated out for 2025:

- Power electronics density is 100 kW/L
- Power electronics target is greater than 100 kW (approximately1.2 kV/100 A)
- Power density target for drive system is 33kW/L
- Cost target for drive system is $6/kW
- Operational life of drive system is 300,000 miles.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer asserted that $100,000 may not be enough to carry a comprehensive work.

Reviewer 2:
The PI has sufficient resources including collaborations with ORNL and NREL in DOE VTO’s Consortium.

Reviewer 3:
Resources are sufficient for next steps. Role of collaborators should be provided in more detail going forward.

Presentation Number: elt223
Presentation Title: Component Testing, Co-Optimization, and Trade-Space Evaluation
Principal Investigator: Jason Neely (Sandia National Laboratories)

Presenter

Jason Neely, Sandia National Laboratories

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 33% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

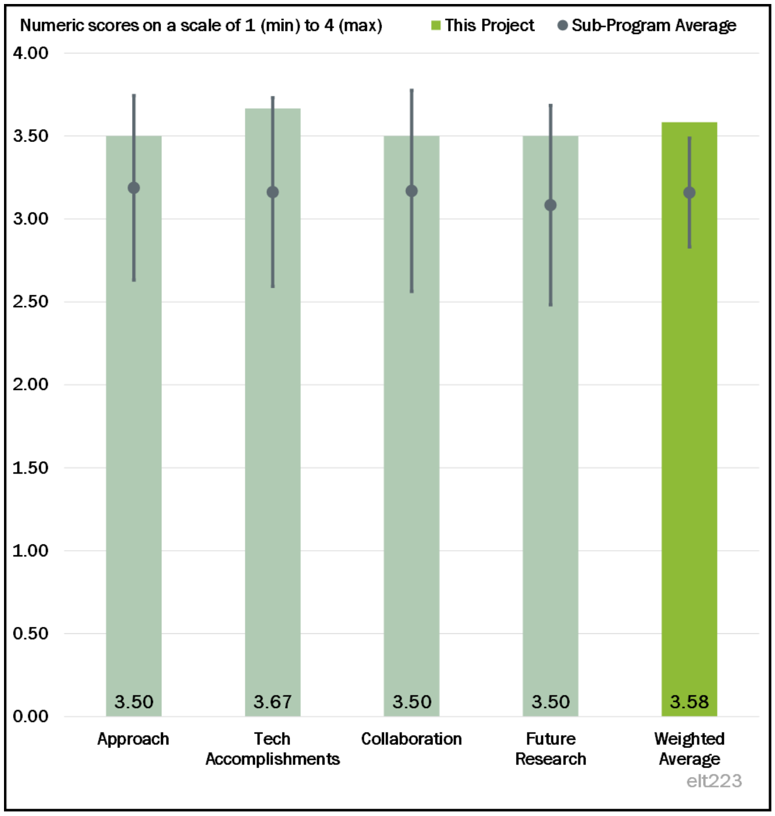

Figure 4-34 - Presentation Number: elt223 Presentation Title: Component Testing, Co-Optimization, and Trade-Space Evaluation Principal Investigator: Jason Neely (Sandia National Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer liked the approach to searching for the best design using optimization. A full exploration of the design is needed to figure out how best to meet project targets.

Reviewer 2:

The project is very well defined and connected.

Reviewer 3:

The approach is sound because it includes component testing, sub-system models, and full system optimization of the integrated electric drive system.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Excellent work on creating and validating detailed circuit design tools.

Reviewer 2:

Accomplishments include a drive test bed for evaluating GaN devices, device level analysis of SiC versus GaN devices, boost converter optimization using Genetic algorithm optimization (GA), a novel inverter architecture, and a high-fidelity circuit model for inverter drive. This is an impressive list.

Reviewer 3:
Please continue this project.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project pulls in expertise from different organizations to achieve synergistic results.

Reviewer 2:
The team is well defined and resources leveraged.

Reviewer 3:
Collaboration and coordination with Purdue (motor/drive co-optimization), Lehigh University (GaN devices), and SUNY Poly (fabricating SiC JBS diode) is proceeding well.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
These people know what they are doing.

Reviewer 2:
The hardware build is an important next step.

Reviewer 3:
Optimizing the system for 100 kW peak/55 kW continuous and building a scaled prototype is a good plan forward for 2020. Plans for 2021 include developing an advanced AC filter, co-optimizing inverter and homo-polar motor, and building an inverter using SNL's GaN devices are also sound.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is important in finding an optimal inverter design to meet DOE VTO’s drive unit targets.

Reviewer 2:
The reviewer found good research at the edge of commercialization.

Reviewer 3:
This project supports the overall DOE objectives of creating a compact, efficient, cost-effective 33 kW/L drive system.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer would not hesitate to increase resources by 20%—good value for the money.

Reviewer 2:
Project appears to be meeting technical goals and timing with the funding provided.

Reviewer 3:
FY 2020 funding of $350,000 is adequate for the stated objectives.

Presentation Number: elt234 Presentation Title: Soft Magnets to Achieve High-Efficiency Electric-Drive Motors of Exceptional Power Density Principal Investigator: Matthew Kramer (Ames Laboratory)

Presenter

Matthew Kramer, Ames Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

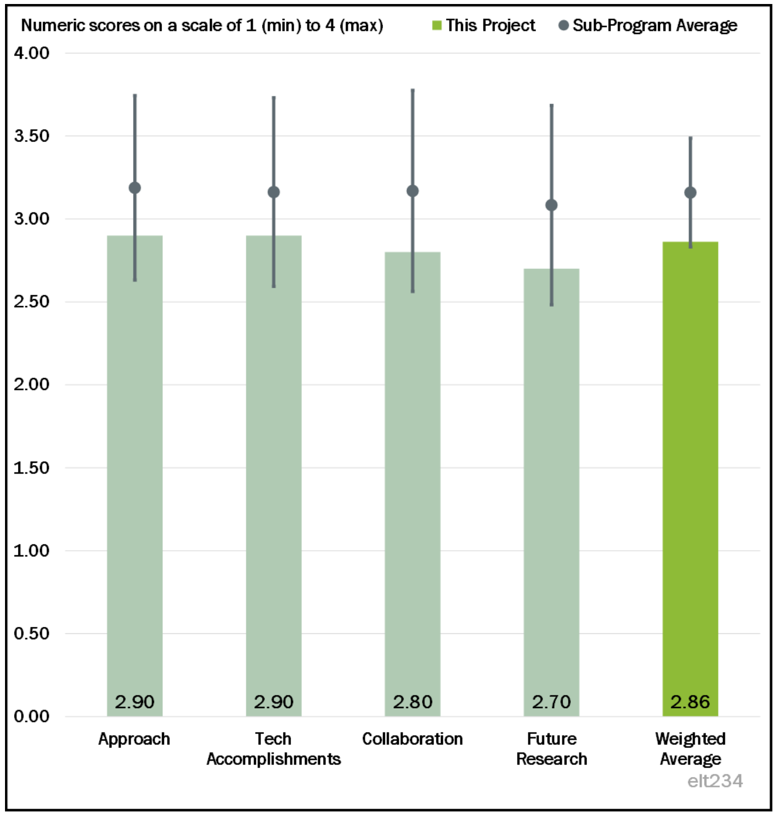

Figure 4-35 - Presentation Number: elt234 Presentation Title: Soft Magnets to Achieve High-Efficiency Electric-Drive Motors of Exceptional Power Density Principal Investigator: Matthew Kramer (Ames Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach to the project is sound. Technical barriers are being addressed adequately.

Reviewer 2:

The project has a very clearly defined target, and the approach to performing work clearly reflects that. The ability to fully manufacture test strips and characterize them provide sufficient proof points.

Reviewer 3:

In the overview slides, the PI mentioned that two barriers were addressed, Barrier 1: Magnet cost and rare-earth element price volatility, Barrier 2: Non-RE electric motor performance to meet the Targets—Exceptional drive motor power density and reduced cost (50 kW/l at $3.30/kW). However, in the presentation it is not clear how this material compares with the state-of-the-art 0.27 millimeter (mm) or 0.25 mm Si steel in terms of flux density, core loss at different frequencies up to 1000 Hz, and mechanical properties. Without this comparison, it is not possible to claim that the cost barrier and performance barrier are addressed.

Reviewer 4:

There seems to be overlap between this project and ELT091; this needs to be clarified.

Reviewer 5:

This project develops new soft magnetic materials to reduce iron loss and cost and improve power density for traction machines. The team has built some samples and tested the material properties. The loss and efficiency results show a greatly reduced iron loss indeed. The team will be working with an industry partner for large-scale production and to try to reduce the cost.

The reviewer had one question on the improvement of power density. It is not clear how the soft magnetic material developed in this project can compete with some existing material, such as Hiperco 50 in terms of saturation, permeability, and core loss. Hiperco 50 can easily go to 2.5 T. M19 can achieve more than 1.9 T. The material developed in this project targets to achieve 1.8 T, which is much lower than that of Hiperco 50. If the flux density of this material can only achieve 1.8 T, how can this material achieve better power density than Hiperco 50 or M19? No data in the presentation were shown about how the power density of machines can be improved using the materials developed in this project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project has completed all the target milestone for this year. Technical targets have been met with clearly defined and sufficiently exhaustive experiments.

Reviewer 2:
Progress is acceptable to date.

Reviewer 3:
Overall, the team has made great progress in accomplishing the scheduled tasks. Four milestones are planned for year 2, and two milestones have been met, and one milestone is delayed, i.e., 35 mm ribbon. The original plan is to achieve this milestone by the end of quarter 3 of year 2. The presentation shows this task is 50% complete.

Reviewer 4:
Quantitative analysis of what can be achieved in terms of machine performance based on the achieved material properties should be performed.

Reviewer 5:
A sample of the 6.5% Si material has been prototyped. However, how does it compare with the standard Si steel to meet the power density, efficiency and cost targets is still not very clear.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There seems to be proper collaboration and coordination among team members.

Reviewer 2:
There seems to be reasonable collaboration among the three National Laboratories involved.

Reviewer 3:
Each team member has its own expertise to contribute to the project.

Reviewer 4:
OEM partners and electrical steel manufacturing partners are very crucial for a project like this.

Reviewer 5:
The project has established ongoing collaboration with ORNL and NREL to support a system level property test. In addition, an industrial partnership provided needed support for manufacturability study. A deeper timeline and test details will help clearly understand the support needed from NREL and ORNL.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
This is really excellent. The manufacturing partnership will really help understand the requirement on scalability of the concept. More details from the NREL and ORNL study are needed to understand this part.

Reviewer 2:
Proposed future work is well aligned and planned, per the project objectives.

Reviewer 3:
The team identified three challenges: scalability of material, optimizing coreless while maintaining manufacturability, and cooling technology during material fabrication. The team's future plan proposes work to tackle these three challenges. The planned future work is reasonable and follows a logical manner.

Reviewer 4:
Quantification of machine performance improvement should be included.

Reviewer 5:
The prototype motor manufactured with the 6.5 % Si steel material has to be compared with off-the-shelf automotive grade traction motor having similar dimensions, voltage, current, speed, and cooling constraints. Without this validation, it is not clear the contribution of this project in improving the power density, efficiency, and cost reduction. Only some of these aspects have been addressed in the future research plan.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is relevant and well aligned with DOE objectives in 2025.

Reviewer 2:
This project claims to support the DOE objectives for power density, efficiency, and cost. However, without substantial comparison and validation, this is not confirmed.

Reviewer 3:
Yes. Efficient improvement in the motor will help meet the objective on energy density.

Reviewer 4:
This project supports the overall DOE objectives as this project develops soft magnetic materials for vehicle traction motors with reduced iron loss, improved power density, and low cost.

Reviewer 5:
The project is relevant, but its expected quantitative impact is not clear.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources seem to be adequate.

Reviewer 2:
Resources are sufficient.

Reviewer 3:
The project has sufficient collaboration and personnel support.

Reviewer 4:
The team has absolutely sufficient facilities and resources to achieve the stated milestones.

Reviewer 5:
The project might show a 6.5% Si steel material at the end. But is it going to be superior to the materials already available?

Presentation Number: elt236
Presentation Title: Direct-Current Conversion Equipment Connected to the Medium-Voltage Grid for Extreme Fast Charging Utilizing Modular and Interoperable Architecture
Principal Investigator: Watson Collins (Electric Power Research Institute)

Presenter

Watson Collins, Electric Power Research Institute

Reviewer Sample Size

A total of one reviewer evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

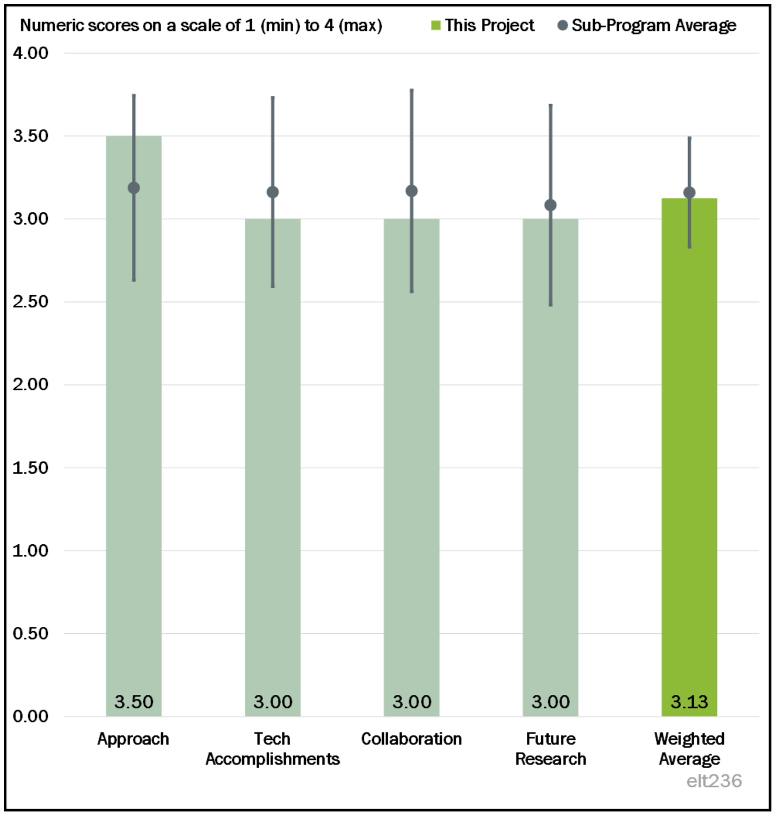

Figure 4-36 - Presentation Number: elt236 Presentation Title: Direct-Current Conversion Equipment Connected to the Medium-Voltage Grid for Extreme Fast Charging Utilizing Modular and Interoperable Architecture Principal Investigator: Watson Collins (Electric Power Research Institute)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project is addressing cost of ownership, efficiency, and footprint which are critical for commercialization and scale of fast charging.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Completion and status of milestones are not clear from the presentation. From information provided during the presentation, it appears that the project is on schedule.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Partner roles are clearly defined.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Future research is outlined within project and is sensible, and challenges that could materialize in budget period two have been identified.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project addresses cost of ownership, efficiency, and footprint, which are critical for commercialization and scale of fast charging.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project is resourced sufficiently to achieve milestones in a timely manner.

Presentation Number: elt237
Presentation Title: Enabling Extreme Fast Charging with Energy Storage
Principal Investigator: Jonathan Kimball (Missouri S&T)

Presenter

Jonathan Kimball, Missouri S&T

Reviewer Sample Size

A total of one reviewer evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

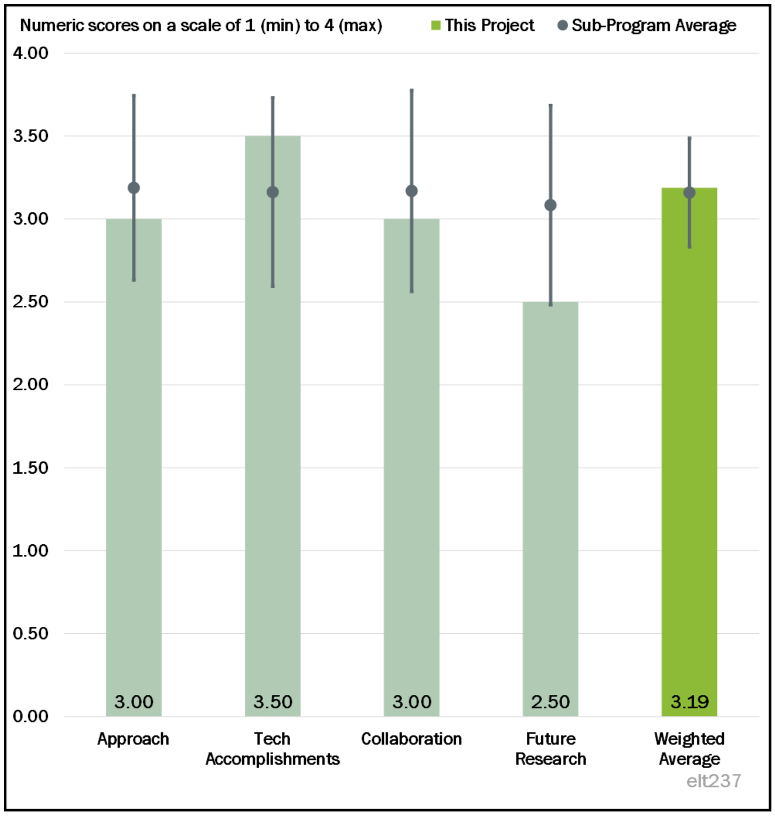

Figure 4-37 - Presentation Number: elt237 Presentation Title: Enabling Extreme Fast Charging with Energy Storage Principal Investigator: Jonathan Kimball (Missouri S&T)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project could better define a "business as usual (BAU)" scenario and compare the key outcomes and benefits of the work against this BAU case. The project should have better defined targets (capacity fade, lifecycle cost). The project could better highlight the tradeoffs between potential charge time and impacts on energy storage.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The project seems to be on time and on schedule to reach its goals.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The project could benefit from more collaboration with a power electronics manufacturer or supplier to better set real-world expectations.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The project would benefit from showing better alternative options or at least comparing the chosen approach to the others.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

This project will help define possible solutions to advanced and low-cost vehicle charging.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

Resources seem sufficient.

Presentation Number: elt238
Presentation Title: Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State Direct-Current Protection
Principal Investigator: Srdjan Lukic (North Carolina State University)

Presenter

Srdjan Lukic, North Carolina State University

Reviewer Sample Size

A total of one reviewer evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

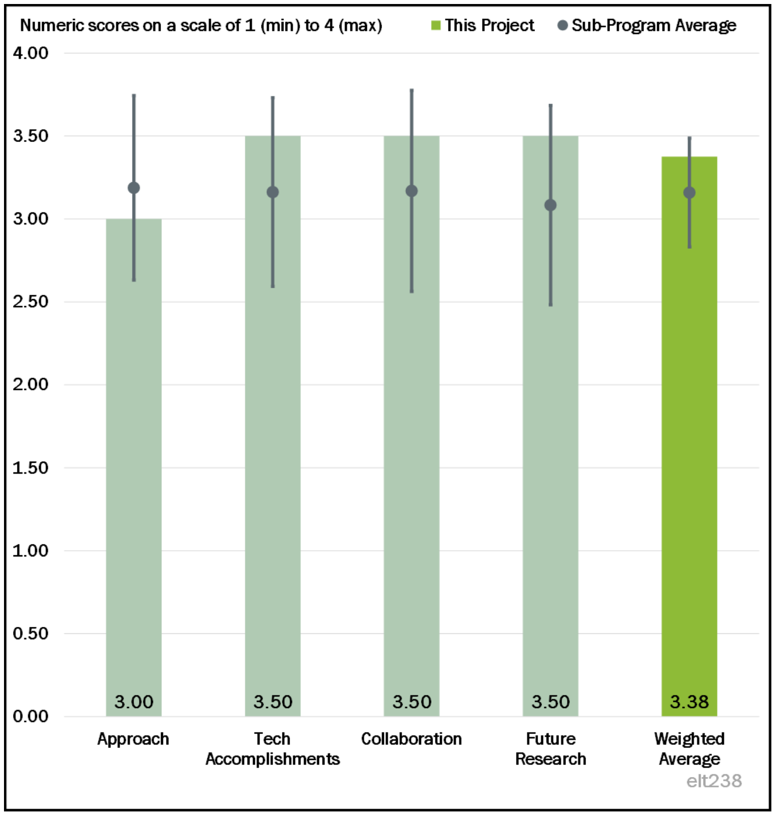

Figure 4-38 - Presentation Number: elt238 Presentation Title: Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State Direct-Current Protection Principal Investigator: Srdjan Lukic (North Carolina State University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

It would be helpful if the review explained the reasoning behind the 480 V versus high voltage—economic or technical benefits of this approach. It would also be helpful if the review clearly explained why a solid-state transformer was chosen or beneficial over conventional approach.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

It seems that good progress has been made.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Coordination and communication across partners seem good, but a work breakdown structure or some type of system work plan would help communicate this (i.e., who is working on what piece).

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The project seems focused on a real and upcoming issue.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project will help lower charging costs and enable increased EV adoption.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources seem sufficient when compared to similar efforts that are being funded.

Presentation Number: elt239
Presentation Title: High-Power Inductive Charging System Development and Integration for Mobility
Principal Investigator: Omer Onar (Oak Ridge National Laboratory)

Presenter

Omer Onar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

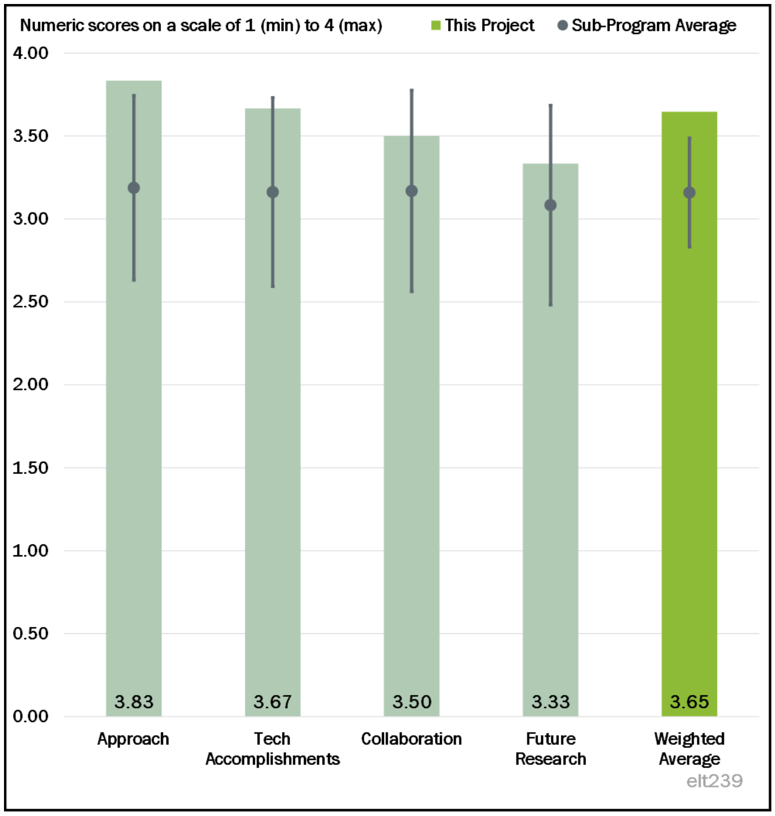

Figure 4-39 - Presentation Number: elt239 Presentation Title: High-Power Inductive Charging System Development and Integration for Mobility Principal Investigator: Omer Onar (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach is solid with design, testing, modeling, and validation. The integration into a vehicle is key. The project has demonstrated some success with the completion of the go/no-go milestone in October of 2019. There was no mention of impact on the schedule due to COVID-19 related closures which seems unlikely. The reviewer suspected there will be delays for the go/no-go decision point associated with the demonstration at 100 kW on a Hyundai-Kia vehicle.

Reviewer 2:

The project is focused on both 100 kW and 300 kW inductive charging system, designed to be small with electromagnetic coupling. The team seems to have a very specific and detailed approach very well aligned with accomplishing the necessary activities to achieve project goals. In particular, the team has worked to take an approach to overcome shortcomings of existing systems. They have also included analysis of design alternatives, in order to minimize risk.

Reviewer 3:

The approach is logically organized. Initially doing the soft requirements like iterative design and modeling. Later in the project there is demonstration of the 100 kW and the 300 kW systems on actual vehicles.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
A lot of progress appears to have been made over the past year with 4 accomplishments from FY 2019 mentioned and 18 from FY 2020. The laboratory benchtop test setup shows impressive results.

Reviewer 2:
Overall, the project has appeared to achieve significant accomplishments. The team is now working on validating 100 kW operation. So far, they are showing 95% efficiency. The team compared their system against state-of-the-art systems, showing much higher power transfer at a larger air gap and at higher efficiency. During this budget period, they have developed the simulation model and thermal analysis. By conducting detailed analysis, the team has been able to significantly reduce component sizes. Assembly initially turned out to be an issue, so they analyzed alternative designs and chose a different approach. They have also analyzed the vehicle-side equipment **-** with overall efficiencies at 97%–98%. In addition, the team looked at ways to minimize the misalignment issues.

Reviewer 3:
Good accomplishments occurred including the design and prototype, simulation and analysis of the components, and inverter design.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Partners include ORNL (lead), ChargePoint, Hyundai, and Seres—pretty much all the types of organizations needed for this project. The team has very specific duties assigned to each team member. The Hyundai vehicle will be tested up to 100 kW, while the Seres vehicle will be used for 300 kW.

Reviewer 2:
Collaboration was comprised of the National Laboratories, a charging provider, and two automotive companies. Each team member has a distinct piece of the project that compliments the other components. There was not much discussion on the larger vehicle manufacturer since that work is not until the next fiscal year. Look forward to hearing more about that company and its contributions.

Reviewer 3:
It looks like a lot of coordination is occurring and that the right groups are available to do the project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The future work described seems like the next logical steps with this effort. Two areas for future consideration are interoperability with SAE Standard J2954-2, and evaluation of system costs for commercial implementation.

Reviewer 2:
The team appears to have very specific activities left to accomplish, primarily focused on validating up to 100 kW and scale-up to the 300-kW power level. The only concern is that this scale-up may be a significant effort.

After this project, they are also interested in looking at MD and HD applications, which would appear to be a very promising opportunity for this technology. In fact, this technology might actually have greater applications for MD-HD vehicles, particularly delivery trucks and buses. Another future effort identified by the PI was to convert this system from a prototype to a commercial unit.

Reviewer 3:
Future plans are significant. These plans will show and demonstrate the technology.

Will this technology be interoperable with the technology that is occurring with SAE J-2954-2? Several manufacturers are to have the 250-kW wireless charging in small fleets. And new demonstrations are now occurring at the 1000 kW level. It is so important that interoperable mechanisms be used. All wireless vehicles should be able to charge at any wireless interface. It is also important that the 100-kW system be compatible with the 300-kW system.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project supports DOE's overall objectives. If successful this project will provide a prototype for cleaner, more efficient transportation. Work will still be necessary from a cost perspective to get it to commercial market.

Reviewer 2:
The project is focused on improving performance (efficiency and power level) of inductive charging systems, which could add options for charging EVs. This would therefore enable greater use of electric transportation technologies, thereby displacing petroleum and reducing emissions.

Reviewer 3:
The commercial industry needs high power charging. Wireless is one way.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources seem to be appropriate for the work to be completed.

Reviewer 2:
Funds appear sufficient for this project as currently designed. The technology does seem to have strong potential for follow-on activities.

Reviewer 3:
The reviewer commented so far, so good.

Presentation Number: elt240
Presentation Title: Wireless Extreme Fast Charging for Electric Trucks (WXFC-Trucks)
Principal Investigator: Mike Masquelier (WAVE)

Presenter

Mike Masquelier, WAVE

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 33% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

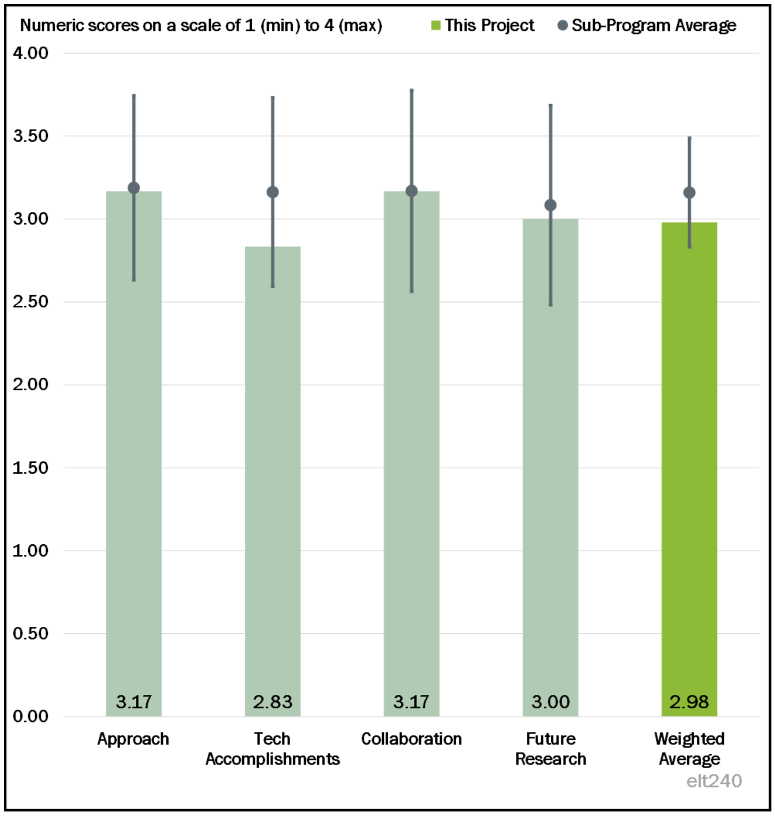

Figure 4-40 - Presentation Number: elt240 Presentation Title: Wireless Extreme Fast Charging for Electric Trucks (WXFC-Trucks) Principal Investigator: Mike Masquelier (WAVE)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The scope of work is sound and it appears that the right project steps and requirements are addressed. One complication appeared to be working with the Port of Los Angeles; however, another location was selected to overcome some of those issues.

Reviewer 2:

The planned approach was sound, but the re-scoped project still focuses on a 500-kW wireless extreme fast-charging (WXFC) unit that has not been fully developed and the project in nearly halfway complete. The team is still making substantial changes to 500 kW hardware. The new plan of moving the 500-kW testing to the third period raises the risk for completion of major milestones.

Reviewer 3:

The approach is directly addressing several XFC technical barriers to include high power wireless power transfer to enable shorter charge times, thermal management, interface to Medium Voltage distribution feeder, and multi-C charge rate of the vehicle battery pack. An improved approach feature would be to have included an initial requirements definition phase prior to the design phase.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
One of the seven converter modules have been developed and tested for full-power operation. Other subcomponents of the high-power charger have been designed, built, and tested. Truck demonstrator #1 already 90% completed (with COVID delaying final completion until July 2020).

Reviewer 2:
As stated above, project looks to adjust its plan based on hardware progress for the grid side, and there has been some good progress there. Recognition of the lack of progress of a 3C-capable large energy storage system (ESS) pack suitable for a HD application is not a sufficient plan to ensure a properly developed vehicle will be available for testing required to show system capability.

The test site is nearly ready and the first truck should be available next quarter. The estimated date for full system testing start was not clear.

Reviewer 3:
Progress on critical standalone battery tests have been delayed which indicates that significant project risk exists halfway through the timeline. The future work to validate that Medium Voltage (MV)-related high voltage isolation requirements from UL field evaluation also indicates that significant project risk remains. The project is only 35% complete nearing second year of work. However, the work completed to date is valuable to overcoming some technical barriers and meets or exceeds the target measures of performance for those components.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The presentation indicates that the partners are meeting regularly to communicate and resolve issues.

Reviewer 2:
There appeared to be some issues with the primary site partner; however, that has been addressed and moved to a new Carson location. This is not without issue as it will entail facility modifications; however, the team appears ready to tackle this barrier.

Reviewer 3:
With the exception of the previously noted ESS subsystem development issues, there seems to be a good representation of the partners needed to make good progress and have an impact.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The presentation does a nice job of ordering the proposed future research by criticality of the needed advancement to the long-term success of this high-power charging capability.

Reviewer 2:
The proposed future research topics listed in the slides are important; however, this question is more directed at the current project (and not future ones). The slides do not directly address how these issues are to be planned around (for instance, thermal management at such high battery charging power).

Reviewer 3:
The difficulties in getting the site ready for a pilot project should be identified as a barrier that needs better understanding within the future work. Similarly, the lack of ability to test the entire subsystem prior to truck installation and operation deserves attention. Completing subsystem testing and reporting data regarding systems parameters and performance in various operational scenarios would yield valuable information for future project.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is highly relevant to DOE's objective to advance transportation electrification technologies with regard to developing high-power charging technologies and EVSE infrastructure capabilities.

Reviewer 2:
Fast-charging, whether for HD or light-duty (LD) applications, is a critical technology to tackle in order to gain better penetration in the EV market. This project directly goes after this.

Reviewer 3:
As explained in the project intro, there is a great deal of energy consumed (and carbon dioxide [CO_2] emissions created) by this portion of the transportation fleet. Efforts which may expand electric mobility into the HD industry are worthy of investigation.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The delayed progress and extended development timeline are likely indicators of insufficient project resources. The technology scope of this project is broad and therefore there is more opportunity for unanticipated development costs.

Reviewer 2:
It is a bit early in the project and the project is relatively aggressive; however, good progress has been made (about 35% complete).

Reviewer 3:
Good partnership members having adequate experience and providing substantial cost share—and hardware, which will allow the project to have substantial impact even if the ultimate milestones are not achieved.

Presentation Number: elt241
Presentation Title: High-Efficiency, Medium-Voltage Input, Solid-State, Transformer-Based 400-kW/1000-V/400-A Extreme Fast Charger for Electric Vehicles
Principal Investigator: Charles Zhu (Delta Electronics)

Presenter

Charles Zhu, Delta Electronics

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

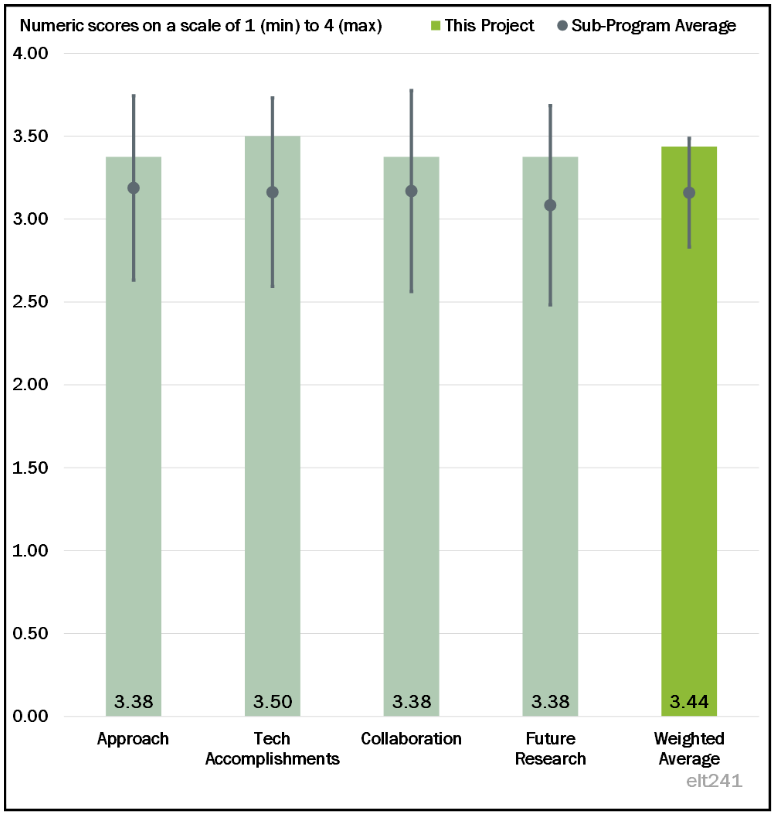

Figure 4-41 - Presentation Number: elt241 Presentation Title: High-Efficiency, Medium-Voltage Input, Solid-State, Transformer-Based 400-kW/1000-V/400-A Extreme Fast Charger for Electric Vehicles Principal Investigator: Charles Zhu (Delta Electronics)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The team has a reasonable project design, going through an interim-level charging system first (135 kW). Time will show if the scale-up from 135 kW to 400 kW can be properly accomplished. The team understands that higher-level systems have increased transmission and distribution requirements, and they are working to reduce some of that need by converting electricity down to the medium level for this charger. Eventually, the system will handle 200-1,000 VDC, though right now they're looking at 400 VDC. They are shooting for 60% charge in 10 minutes at a maximum of 400 amps. The system is also designed to integrate with storage, to address potential demand charge concerns.

Reviewer 2:

The project milestones for BP 1 have all been met and all but the final demonstration of the 400-kW laboratory test for BP 2 have been met. Partial demonstration of the 400-kW test demonstrates compliance at partial power.

Reviewer 3:

The concept is excellent, but not far along enough to give a legitimate observation. The concept would solve a lot of charging time issues for a quick fleet turnaround.

Reviewer 4:
This project is relying upon compelling technologies and hence adopted approach for project is likely to lead to a successful project outcome. Medium-voltage AC input, 4.8 kV or 13.2 kV. Solid state transformer-based technology to reduce the size and weight, and to increase scalability and flexibility. Cascaded multilevel converter topology as medium voltage interface to reduce the total number of power cell. Multilevel resonant converter for medium voltage isolation, operated at high frequency with soft switching. SiC MOSFET devices for high voltage and lower loss. Interface to an ESS and/or a renewable energy generation system (e.g., photovoltaics [PV]) for energy back-up.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
So far, the team has completed the 135-kW charger integration—this is the interim step. This was demonstrated at a higher efficiency level than required. They have also completed the 400-kW mechanical design (early, as it was projected for August 31, 2020) and will be starting testing soon. (There have been some testing delays due to COVID-19.) General Motors (GM) has been working on a retrofitted vehicle with an 800V battery pack (a luxury SUV) to enable faster charging. The requirement is 50% state of charge in 10 minutes, and the project team is already seeing around 67%.

Reviewer 2:
Partial demonstrations are already complete with plans for the final demonstration well underway. The project appears to be on time.

Reviewer 3:
So far, conceptually, it appears to be on track with accomplishments and timelines.

Reviewer 4:
Parts for the 135-kW charger system are under development and likely to be tested as per the project plan. Test conditions for 135 kW charger system are stated out during presentation as well as in project report. It is proved by the PI that resonant converter used in isolation stage will lead to higher efficiency and proved out by measured data indicating charger efficiency greater than 98%. Buck converter efficiency at various charging voltage (200 V to 990 V) is measured. Measured data on efficiency and system waveforms (current and voltage) indicate that the project team has established functionality of parts used in the proposed charger. Proposed prototype of charger is retrofitted in vehicle and charging profile results are included in project report. Also, the project has completed numerous milestones showing outstanding technical progress and accomplishments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project has a good group of team members—an EVSE manufacturer lead with a vehicle manufacturer, two utilities, a state energy office, a university, and a city. Each seems to have a clear role and have been contributing significantly.

Reviewer 2:
Project targets and deadlines were met; the collaborative team appears to be functioning very well.

Reviewer 3:
It appears like all the right groups are lined up to make a successful trial at this stage.

Reviewer 4:
This project lead by Delta Electronics Americas Ltd. includes many relevant collaborators, such as GM, DTE Energy, the Center for Power Electronics Systems at Virginia Tech, NextEnergy, and Michigan Energy Office.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Overall, the project team appears to have a straightforward plan for the remainder of this project. Their plan for future research is to scale up to the 400-kW unit—this may turn out to require a significant effort versus the 135-kW system tested so far. They will test with DTE next year, and then would like to approach the market—this is a market-intended design. There was no indication as to whether any follow-on efforts are planned or even contemplated.

Reviewer 2:
Hardware demonstration of the concept in the third budget period will serve as an excellent technology demonstration of the proposed fast charging system.

Reviewer 3:
The future research seems to go in logical order from this time standpoint.

Reviewer 4:
The proposed future research includes relevant tasks and topics such as test vehicle high voltage distribution system)/rechargeable energy storage system (RESS) with sub-topics; Test 400 kW XFC system with vehicle emulator, test 400 kW XFC system with Chevy Bolt car. Also, included the proposed future research are build test vehicle and test 400 kW XFC system with 800 V retrofit vehicle.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is focused on increasing the charging rate for EVs, to make recharging closer to the gasoline-level experience. That will be important to assist market penetration of EVs.

Reviewer 2:
In order to increase adoption of non-petroleum energy sources for transportation, development and integration of fast-charging systems will be key. This project will demonstrate such a technology.

Reviewer 3:
This would definitely aid in a business case for electric transport vehicles with the concern about charging times.

Reviewer 4:
The project aligns with DOE VTO objectives and successful completion of this project will accelerate adoption of battery powered passenger cars in the United States.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources appear sufficient at this time.

Reviewer 2:
The team appears to be hitting targets on time; funding and resources seem appropriate.

Reviewer 3:
At this moment it seems like the team has what they need to complete the project.

Reviewer 4:
Resources for project seem appropriate.

Presentation Number: elt242
Presentation Title: Heterogeneous Integration Technologies for High-Temperature, High-Density, Low-Profile Power Modules of Wide Bandgap Devices in Electric-Drive Applications
Principal Investigator: G.Q. Lu (Virginia Tech)

Presenter

G.Q. Lu, Virginia Tech

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers indicated that the resources were sufficient, 50% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

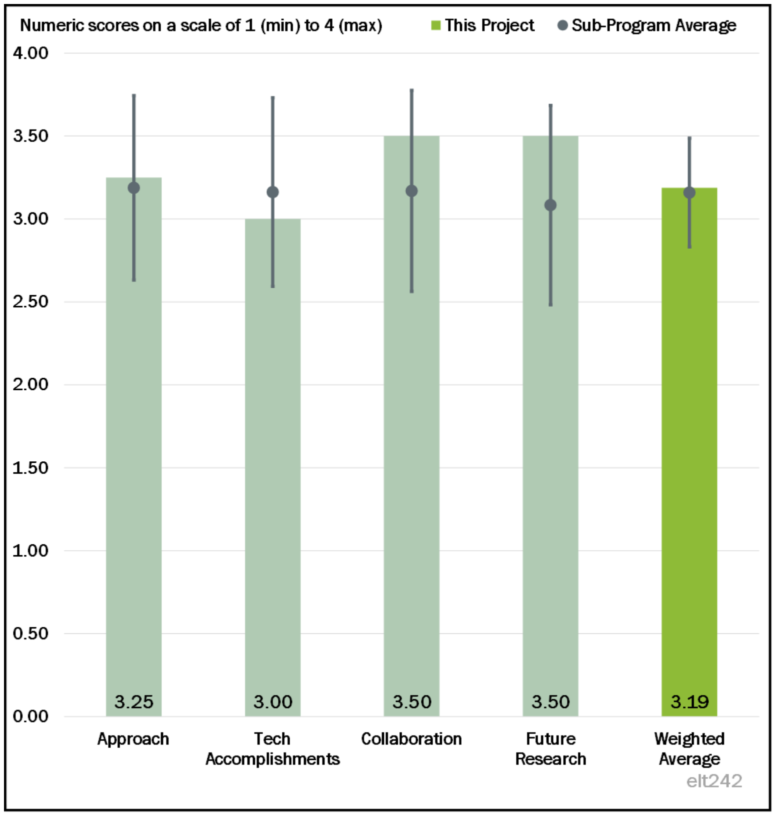

Figure 4-42 - Presentation Number: elt242 Presentation Title: Heterogeneous Integration Technologies for High-Temperature, High-Density, Low-Profile Power Modules of Wide Bandgap Devices in Electric-Drive Applications Principal Investigator: G.Q. Lu (Virginia Tech)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project aims to produce power modules with high-temperature reliability. Experimental approach is designed very well. However, the project does not provide any details on key issues, such as mechanical and thermal simulations. Without details on actual and operational temperature distribution within the module, it might not be possible to exclude some components.

Reviewer 2:

The project addresses the technical barriers from a design perspective. The concern the reviewer had is that manufacturing methods and processes significantly influence performance of a part. There really needs to be production scale manufacturing involvement in the project to ensure results are usable by industry.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The design work and testing show progress, but testing needs to be performed over the full operating temperature before saying the work contributes to overcoming barriers.

Reviewer 2:
The project has finished its first set of designs and experiments; however, there is a significant lack of detail on thermal and mechanical simulation work.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Various project collaborators are listed, and there appears to be good testing and characterization planning embedded in the project.

Reviewer 2:
This is a good team, but the project really needs industry involvement from a power module manufacturer.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
A thorough test plan needs to be developed and testing performed in order to prove these designs have merit.

Reviewer 2:
This is a very relevant topic with well-defined future research targets.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This work is needed to increase power density and fully utilize SiC switches.

Reviewer 2:
The project will contribute significantly in meeting DOE goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources are sufficient.

Reviewer 2:
This area of work is critical, but the reviewer believed the funding level is the contributing factor for why testing is limited and industrial involvement does not exist.

Presentation Number: elt243
Presentation Title: Integrated Motor and Drive for Traction Applications
Principal Investigator: Bulent Sarlioglu (University of Wisconsin)

Presenter

Bulent Sarlioglu, University of Wisconsin

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

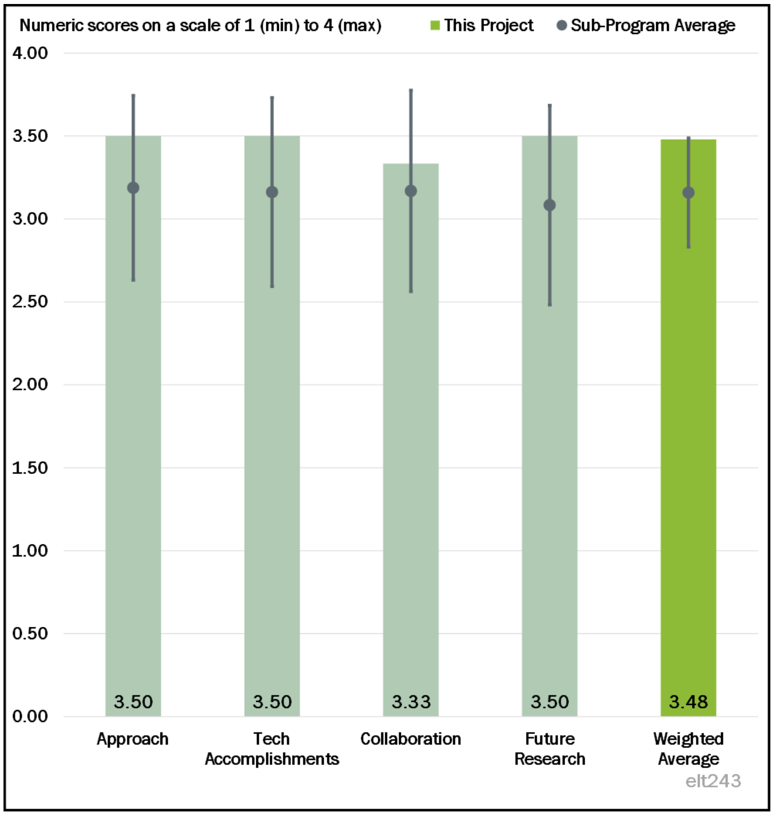

Figure 4-43 - Presentation Number: elt243 Presentation Title: Integrated Motor and Drive for Traction Applications Principal Investigator: Bulent Sarlioglu (University of Wisconsin)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project looks at a wide variety of options and attempts to rationalize the down-selection of the “best” design.

Reviewer 2:

The approach in this project of evaluating various machine and inverter topologies, prototyping the most promising design, and testing to validate the concepts is sound.

Reviewer 3:

The approach is very relevant to industry.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Excellent progress has been made on analyzing the options and picking a best candidate motor and inverter.

Reviewer 2:

The trade-off study showing the SPM motor and the 2-level current source inverter with DC/DC converter as being the leading candidates is well executed and impressive. The integrated motor drive architectural study as well as the test-bed design are also well executed.

Reviewer 3:
The project just started.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team seems to be gearing up to engage.

Reviewer 2:
Collaboration and coordination with NREL and ORNL are proceeding well.

Reviewer 3:
The reviewer found good collaboration with the National Laboratories. It is interesting that the "National Laboratories" keystone project is focusing on a different design. Did the various parties have a discussion about the "best" option?

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The next steps are appropriate.

Reviewer 2:
The project is going in the right direction.

Reviewer 3:
The future plan to complete the hardware prototypes and validate the proposed concepts is sound.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This is a highly desirable project from the industry perspective.

Reviewer 2:
Wisconsin Electric Machines and the Power Electronics Consortium's effort act as a good point of comparison for a bake-off between IMD concepts. This is needed to achieve the technical knowledge required to meet the DOE VTO electric drive targets.

Reviewer 3:
This project attempts to create a compact, cost-effective, and efficient integrated drive to meet DOE's 33 kW/L and $6/kW targets.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project appears to be on schedule with the existing funding level.

Reviewer 2:
FY 2020 funding of $300,000 is adequate to meet the objectives.

Reviewer 3:
This reviewer commented that resources seem appropriate if the collaboration does not extend significantly.

Presentation Number: elt244
Presentation Title: Next-Generation, High-Temperature, High-Frequency, High-Efficiency, High-Power Density Traction System
Principal Investigator: Robert Pilawa (University of California at Berkeley)

Presenter

Robert Pilawa, University of California at Berkeley

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

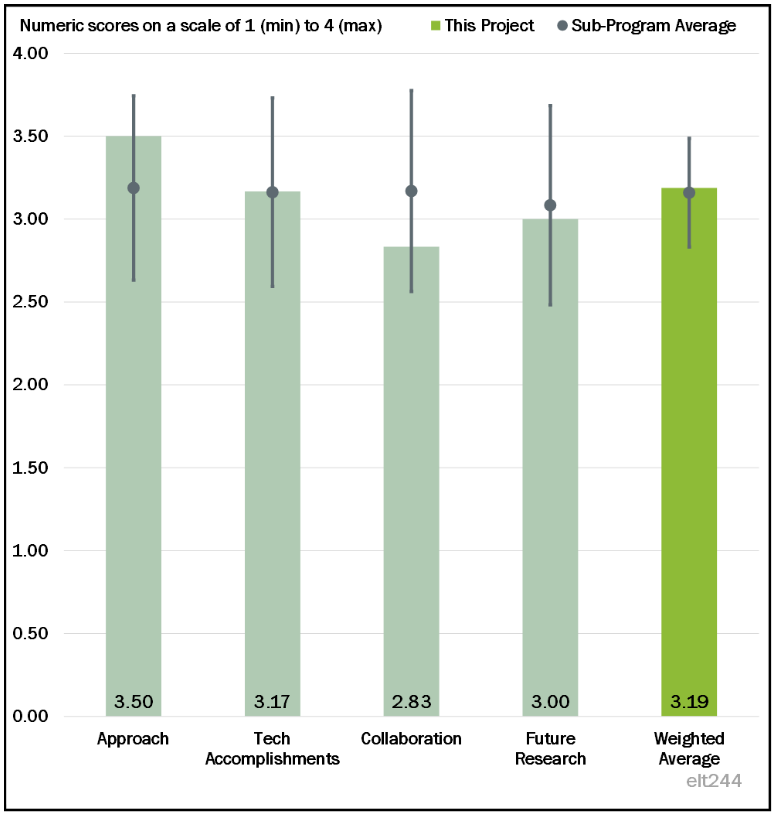

Figure 4-44 - Presentation Number: elt244 Presentation Title: Next-Generation, High-Temperature, High-Frequency, High-Efficiency, High-Power Density Traction System Principal Investigator: Robert Pilawa (University of California at Berkeley)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project team has proposed a novel way to increase the power density of the inverter while reducing the cost at the same time. The barriers have been addressed through novel circuit topologies, component identification and characterization, and packaging. Very interesting work with high potential for commercialization.

Reviewer 2:

The PI states that the Flying Capacitor Multilevel (FCML) converter could be a better power converter topology compared to conventional two-level converter. Distributed heat generation in FCML converter could mitigate reliability issues. Also, the FCML converter could operate under failures, only faction of capability could be compromised under single point failure. The FCML converter with lowest possible inductance in current loop produces less than 1% total harmonic distortion (THD) and could be quite useful for a low-inductance light-weight electric motor drive system. Up to 100 kHz switching frequency allows appropriate voltage balancing in passive components used in the FCML.

Reviewer 3:

The design has potential, but the reviewer asked how it impacts cost. This needs to be addressed before moving forward.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Assessment of the preliminary design has been completed, verifying the electric drive inverter with power density. More than 100 kW/L is achievable.

Reviewer 2:
FCML converter start-up has been verified for voltage ramp-up verified 0 V to 1000 V in few seconds and voltage balancing of passive components achieved by novel PWM control for switches (active elements) and capacitors (passive elements). Fault mitigation method by sensing rate of rise of current through output inductor is investigated by project team. Component characterization including use of automotive qualified part is thought out by the project PI. Based on design and test data, it is stated by PI that projected power density could significantly increase if liquid cooling including immersion cooling is used for the FCML converter.

Reviewer 3:
The work being performed is of high quality and technically interesting, but the design complexity makes it unlikely to be useful for automotive.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project showcases very good collaboration with Consortium members: Purdue University and the University of Wisconsin for machine integration, SNL for WBG expertise and packaging, and ORNL for vehicle integration aspects. Lots of collaboration is shown with components suppliers: GaN Systems, EPC, Infineon, Texas Instruments, TDK, and Murata. Efforts have been made to touch base with OEMs as well.

Reviewer 2:
Input from Industry that could use FCML converter is lacking, else PI collaborates and seeks input from SNL and ORNL

Reviewer 3:
There is little to no evidence of collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
A very clear plan has been outlined on the proposed future research with go/no-go decisions. The main issues on the high-power density, high-efficiency inverter is electromagnetic interference (EMI), thermal management, and novel control development. All these aspects have been planned well at this stage.

Reviewer 2:
Future research includes the following relevant topics: EMI testing, hierarchical control development, development of liquid heat-exchanger or immersion-based thermal management, accelerated lifetime testing of modules, improvement in module's assembly process, development of on-line fault detection and mitigation, and synthesis top-down and bottom-up failure models during design stage.

Reviewer 3:
Without a cost assessment and an understanding that vehicle OEMs concur with this approach, the reviewer would not move forward.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Achieving a very high-power dense traction inverter, which is highly efficient with low cost, is the main objective of the DOE, which is addressed in each and every aspect of this project.

Reviewer 2:
The FCML plans to meet $2.70/kW cost target and 100 kW/L power-density target. This reviewer suggested that the PI must develop metrics and methods by using bill of material and part dimensions to track cost and power-density targets.

Reviewer 3:
The technology is interesting, and it is clear that advantages can be yielded, but the reviewer was really concerned if this project has merit for automotive use.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The team is very well organized and capable to deliver the required tasks.

Reviewer 2:
The project has necessary and sufficient resources.

Reviewer 3:
If the DOE objective is to have some projects to explore really different approaches, then this level of resources is sufficient.

Presentation Number: elt245
Presentation Title: Integration Methods for High-Density Integrated Electric Drives
Principal Investigator: Alan Mantooth (University of Arkansas)

Presenter

Alan Mantooth, University of Arkansas

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

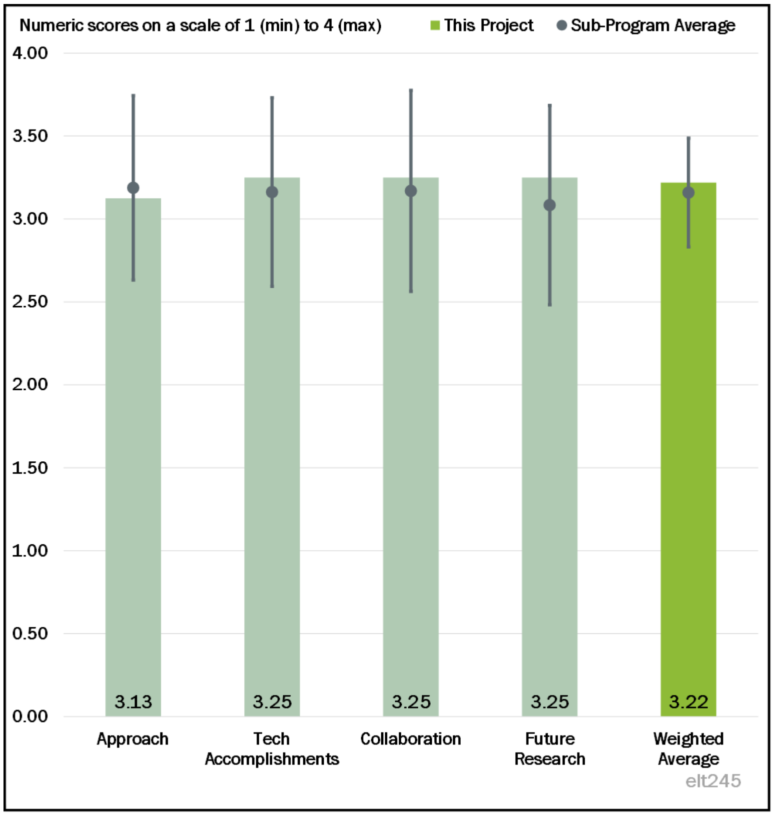

Figure 4-45 - Presentation Number: elt245 Presentation Title: Integration Methods for High-Density Integrated Electric Drives Principal Investigator: Alan Mantooth (University of Arkansas)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach to designing a high-power density power module by integrating gate drivers, current sensors, filtering, and cooling is well received.

Reviewer 2:

The reviewer noted that this is a good project, it has just started, and it seems to be going deep enough.

Reviewer 3:

Since SiC devices are currently on the market, the purpose of the SiC complementary-symmetry metal (CMOS) fabrication task could be made clearer.

Reviewer 4:

Increasing the inverter power density and efficiency, and at the same time reducing the cost, is a very critical area of interest to reduce the cost of EVs and for their market penetration. One aspect is doing the prototype and evaluating the high-temperature gate drive, high power density power module design, and the integration aspects of the power module. The second aspect is whether this is going to deliver the same performance in the field. A series of design validation is needed to prove that the components developed for a traction inverter delivers superior power density and efficiency with lower cost when compared to the off-the-shelf traction inverter. How is this validation going to be performed?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Excellent progress has been made on characterizing SiC low-voltage devices at very high temperatures.

Reviewer 2:
Research is on track with year 1.

Reviewer 3:
The research team has shown evidence of excellent technical progress in characterizing high-temperature operation of SiC CMOS, creating double-sided power module architectures, and exploring various integration components and cooling methods.

Reviewer 4:
A literature review on the power module integration aspects, gate drive design, and integrated circuit design with some FEA and prototype results have been shown. In the trade-off study, has any analysis been done on the effect of the high switching frequency of these devices and the corresponding EMI issues?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project tasks are well coordinated across the project team.

Reviewer 2:
The reviewer commented that there is sufficient collaboration and engagement.

Reviewer 3:
The team has shown solid collaboration with Virginia Tech and ORNL.

Reviewer 4:
The team has been very collaborative with Virginia Tech and ORNL for the power module and integrated circuit design, and heat sink design and system integration aspects, respectively.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The next steps are appropriate in achieving the project goals.

Reviewer 2:
The reviewer found good vision for future research.

Reviewer 3:
Proposed future work on high-temperature CMOS fabrication and continued development of the integrated power module are well motivated.

Reviewer 4:
The milestones and deliverables of each collaborator and the PI have been mentioned clearly. However, the go/no-go decision points have not been listed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Device design for the integrated power inverter is an important contribution to the DOE VTO electric drive targets.

Reviewer 2:
Yes, it is highly desirable.

Reviewer 3:
A compact power module will be critical to DOE's stated goal of creating a 33 kW/L electric drive system.

Reviewer 4:
This project aligns very well with DOE objectives of increasing inverter power density and efficiency while reducing the cost.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project appears to be on track with the given funding.

Reviewer 2:
Sufficient resources have been allocated.

Reviewer 3:
FY 2020 funding of $300,000 is adequate.

Reviewer 4:
The team is well experienced, having worked on similar projects in the past.

Presentation Number: elt246
Presentation Title: Implementation of Wide-Bandgap Devices in Circuits, Circuit Topology, System Integration as well as Silicon Carbide Devices
Principal Investigator: Anant Agarwal (Ohio State University)

Presenter

Anant Agarwal, Ohio State University

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

50% of reviewers indicated that the project was relevant to current DOE objectives, 50% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

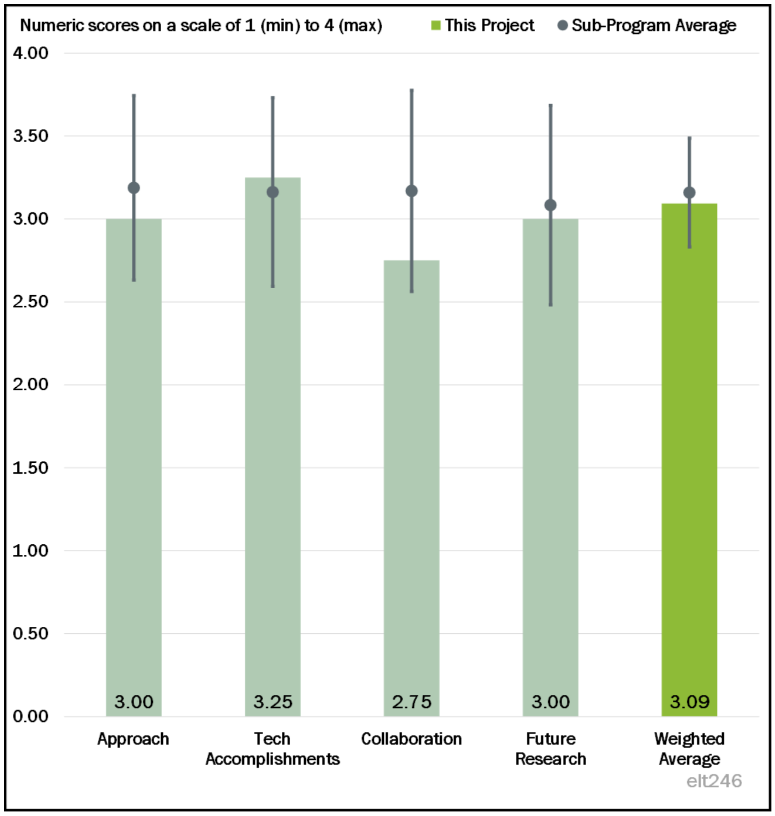

Figure 4-46 - Presentation Number: elt246 Presentation Title: Implementation of Wide-Bandgap Devices in Circuits, Circuit Topology, System Integration as well as Silicon Carbide Devices Principal Investigator: Anant Agarwal (Ohio State University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Generally, the project seems to be addressing issues that exist, but the reviewer was uncertain that these issues have not been already addressed when they compare to ELT082. Usually the auto industry has access to new devices years before the general market.

Reviewer 2:

The project hits the right target application for achieving energy density goals in power electronics. However, there is a clear lack of background understanding. There are SiC based inverters in operation in commercial vehicles today (Tesla for example has a discreet SiC device). Additional study of the reliability data from the past must be included.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The work is interesting and educates the project, but the reviewer was not sure this will contribute to auto industry adoption of WBG devices.

Reviewer 2:

The project has accomplished initially set targets.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project has excellent collaboration.

Reviewer 2:
No device manufacturers or vehicle OEMs are on the team. Without alignment with industry, this work is limiting its potential.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
No evidence has been provided other than from the perspective of the current team that the issues being addressed are appropriate and their resolution would allow industry to deploy WBG in mass. The reviewer cannot say future research will be effective without this evidence.

Reviewer 2:
The project must include additional background study.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project aims to achieve power and energy density objectives as set by DOE.

Reviewer 2:
This work seems to address WBG device issues, and there is a logic behind the project team's thinking. There is quality in the work being performed, but the reviewer did not believe this will enable exploitation of WBG by the auto industry.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Based on what this project is, it has appropriate resources.

Reviewer 2:
Sufficient resources have been included to complete the project plan.

Presentation Number: elt247
Presentation Title: Cost-Competitive, High-Performance, Highly Reliable Power Devices on Silicon Carbide and Gallium Nitride
Principal Investigator: Woongje Sung (State University of New York Polytechnic Institute)

Presenter

Woongje Sung, State University of New York Polytechnic Institute

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

67% of reviewers indicated that the project was relevant to current DOE objectives, 33% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

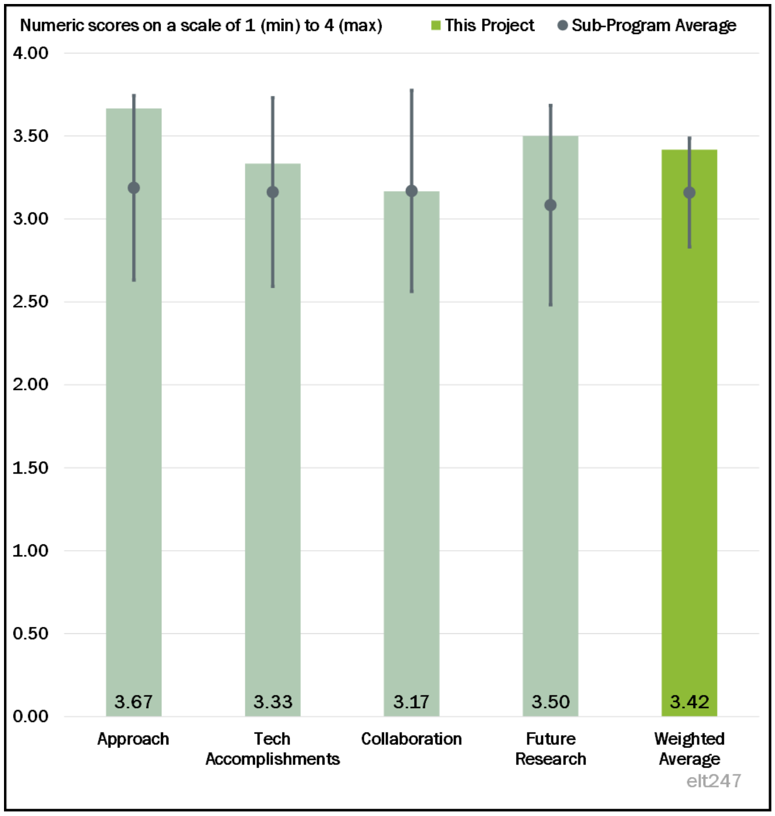

Figure 4-47 - Presentation Number: elt247 Presentation Title: Cost-Competitive, High-Performance, Highly Reliable Power Devices on Silicon Carbide and Gallium Nitride Principal Investigator: Woongje Sung (State University of New York Polytechnic Institute)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
Both BP1 and BP2 plan are well designed, comprehensive, and mostly feasible.

Reviewer 2:
All relevant barriers to technical target are well summarized, and the project has a well-timed staged execution plan.

Reviewer 3:
Generally, the project seems to be addressing issues that exist, but the reviewer was uncertain that these issues are a complete list or the ones the auto industry believes are important.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project has met all technical targets for the current year.

Reviewer 2:
The cell optimization, the edge termination design, and non-isothermal simulation of a narrow junction field effect transistor (JFET) width, and mask design of floor plan show good progress toward the final deliverable. The reviewer hoped that Lot 2 can be finished before August. The evaluation of Lot 1 is satisfying.

Reviewer 3:
The work is interesting and educates the project, but the reviewer was not sure this will contribute to auto industry adoption of WBG devices.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This project is a collaboration between ADI, Ohio State University, SNL and the Army Research Laboratory, which is an excellent distribution of capabilities.

Reviewer 2:
Collaboration with ADI is extensive.

Reviewer 3:
No device manufacturers or vehicle OEMs are on the team. Without alignment with industry, this work is limiting its potential.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed research on process, device, reliability assessment, and packaging research are good topics and carry far-reaching impact.

Reviewer 2:
The proposed future research is well planned and staged according the various intermediate targets.

Reviewer 3:
No evidence has been provided other than from the perspective of the current team that the issues being addressed are appropriate and their resolution would allow industry to deploy WBG in mass. The reviewer cannot say future research will be effective without this evidence.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
A large project like this one to ensure next-generation WGB with reasonable performance is directly related to VTO's 2025 target on power electronics power density and cost.

Reviewer 2:
This project is well aligned with DOE targets of energy density in WBG based devices.

Reviewer 3:
This work seems to address WBG device issues, and there is a logic behind the project team's thinking. There is quality in the work being performed, but the reviewer did not believe this will enable exploitation of WBG by the auto industry.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Based on what this project is, it has appropriate resources.

Reviewer 2:
The project is sufficiently resourced.

Reviewer 3:
Funding of $300,000 per year for 5 years is more than sufficient.

Presentation Number: elt248
Presentation Title: Multi-Objective Design Optimization of 100-kW Non-Rare-Earth or Reduced-Rare Earth Machines
Principal Investigator: Scott Sudhoff (Purdue University)

Presenter

Scott Sudhoff, Purdue University

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 50% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

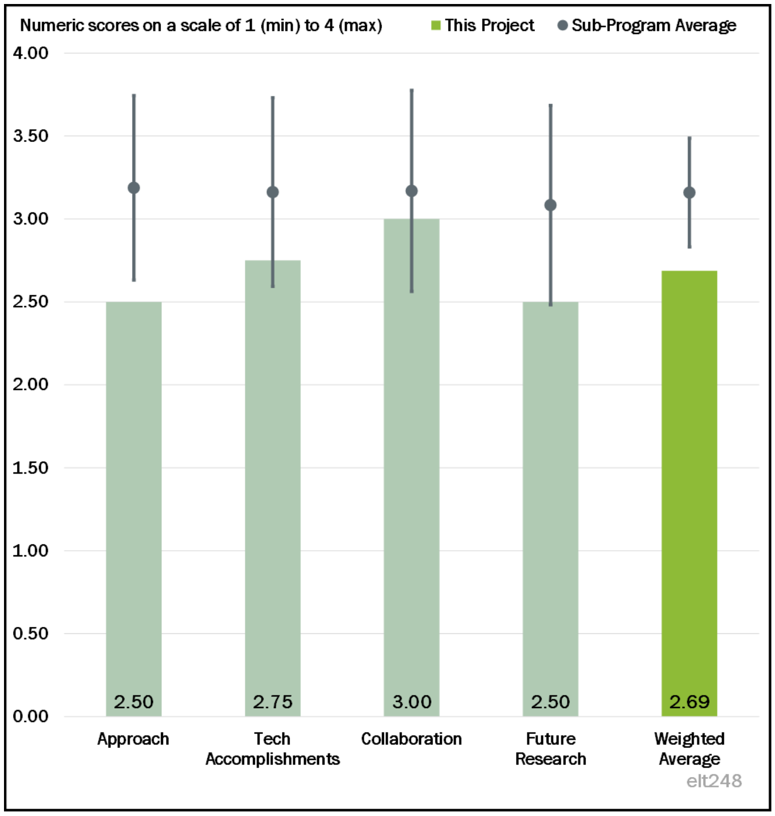

Figure 4-48 - Presentation Number: elt248 Presentation Title: Multi-Objective Design Optimization of 100-kW Non-Rare-Earth or Reduced-Rare Earth Machines Principal Investigator: Scott Sudhoff (Purdue University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project started 12 months ago. At this point, the team has finished the development of the numerical tool, method of moments, to analyze the electromagnetic performance of electric machines. Research results have shown that this numerical tool takes a tremendously reduced time to get similar enough results as a FEA tool. This tool has not started to address the technical barriers stated in the presentation. However, this tool lays the foundation for the team's future work to address the technical barriers, i.e., non-RE machines, reduced cost, and the system-level trade-off between cost, performance, and materials.

Reviewer 2:

The focus has been more on modeling tools, but there has not been enough justification of the selectin of the homopolar topology or how it evolved. Also, not enough information has been provided to quantitatively show the expected improvement compared to the state of the art. In addition, it is not obvious that this topology provides a path to meeting the DOE requirements.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The team has finished all four milestones as planned in the proposal on time. The major accomplishment in Year 1 is the development of the numerical tool for electric machine analysis. The results predicted using this new tool are compared against the results from using a finite element tool. The two produce very similar results. The numerical tool runs significantly faster.

Reviewer 2:
The choice of the homopolar topology is not clearly justified. The proposed design seems fairly complicated, and it is not clear that it can provide a practical path to meeting the DOE objectives.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
All team members run bi-weekly conference calls to follow up on the project. The collaboration and coordination are excellent. The reviewer encouraged the team to publish together.

Reviewer 2:
There seems to be reasonable communications among team members and good collaboration with the team at SNL.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Future research is effectively planned and has a logical manner. The team did not discuss project risks for the future work.

Reviewer 2:
Even though design and modeling tools are important, more emphasis on proving the merits of the proposed topology is needed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project supports the overall DOE objectives as it develops non-RE vehicle traction electric machines and tries to reduce the cost and improve the system reliability.

Reviewer 2:
The project is relevant, but the value proposition is not very clear.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The team consists of leading universities and National Laboratories in the field of electric machines and power electronics. Every organization on the team has excellent facilities and resources to conduct the research tasks in this project.

Reviewer 2:
Resources are sufficient.

Presentation Number: elt249
Presentation Title: Rugged Wide Bandgap Devices and Advanced Electric Machines for High-Power Density Automotive Electric Drives
Principal Investigator: Victor Veliadis (North Carolina State University)

Presenter

Victor Veliadis, North Carolina State University

Reviewer Sample Size

A total of one reviewer evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 0% of reviewers indicated that the resources were sufficient, 100% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

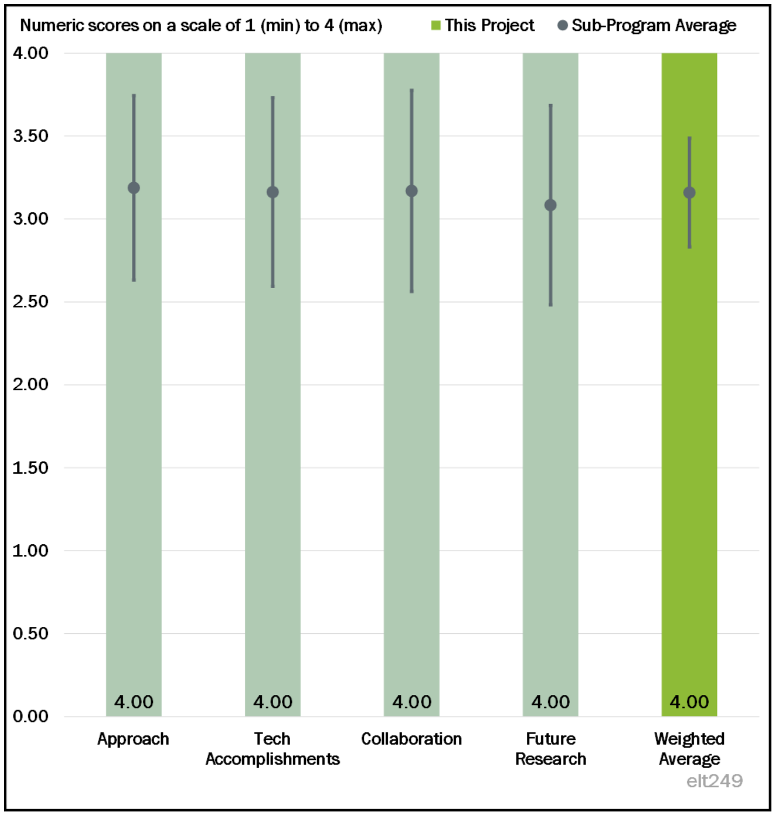

Figure 4-49 - Presentation Number: elt249 Presentation Title: Rugged Wide Bandgap Devices and Advanced Electric Machines for High-Power Density Automotive Electric Drives Principal Investigator: Victor Veliadis (North Carolina State University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This is a comprehensive project consisting of two part: WBG power electronics and a non-HRE high-power density motor. It is impressive to see the team tackle two different topics with equally innovative and effective approaches. The modeling of GaN device validated the impact of high frequency on power density. Going for higher frequency is the only way to achieve 2025 target power density; the motor design evaluation is extensive. Three designs were evaluated using FEA. This is the right approach before building anything.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Both modeling of GaN device and motor designs made good progress. The use of NEOREC45MHF is a reasonable choice for now. However, its high-temperature performance is worrisome. Ames Laboratory has been pursuing high-temperature non-HRE PM via fine grain approach. They reported better performance with an N45 grade magnet than that of the N45UH. Please contact them for high-temperature data. Ultra-conductive Cu conductor improvement in conductivity should be limited to 8% or less. Overall, there has been great progress.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This is one of the projects for the EDT Consortium. The team appears to be periodically reviewed by four National Laboratories.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed efforts on GaN and a demagnetization check on N45MHF are all necessary.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The work this team has been doing directly addresses VTO's 2025 target on system power density.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer asserted that $300,000 per year for 5 years is sufficient for either power electronics or the motor; at least $200,000 per year more is needed for the team to run at full speed.

Presentation Number: elt250
Presentation Title: Design, Optimization, and Control of a 100-kW Electric Traction Motor Meeting or Exceeding DOE 2025 Targets
Principal Investigator: Ian Brown (Illinois Institute of Technology)

Presenter

Ian Brown, Illinois Institute of Technology

Reviewer Sample Size

A total of one reviewer evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

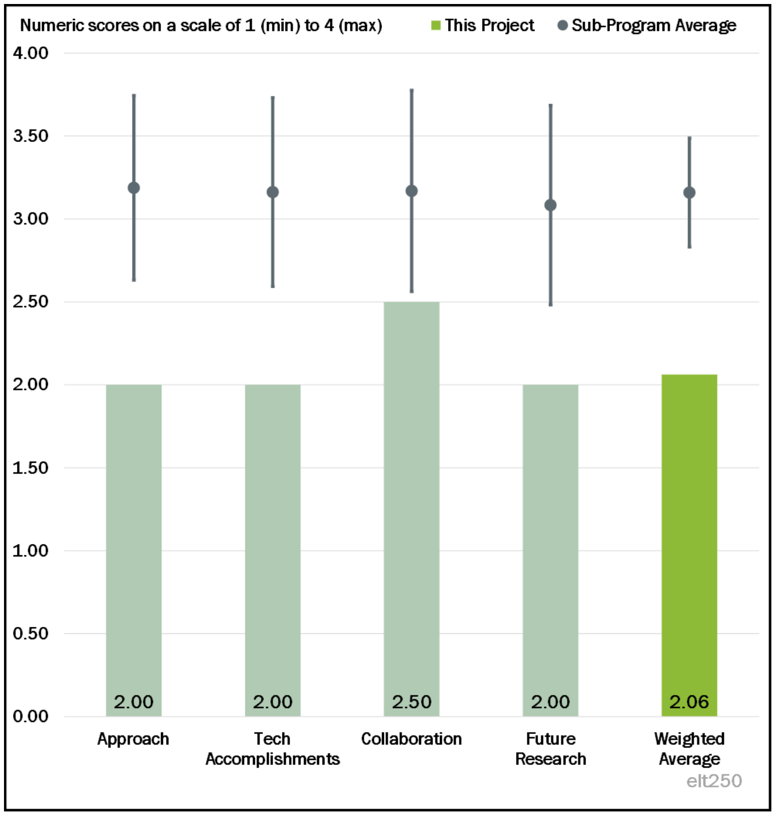

Figure 4-50 - Presentation Number: elt250 Presentation Title: Design, Optimization, and Control of a 100-kW Electric Traction Motor Meeting or Exceeding DOE 2025 Targets Principal Investigator: Ian Brown (Illinois Institute of Technology)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Even though the proposed approach includes multiple technologies, none of them is really novel and it is not clear how this approach can lead to an eight-fold improvement in power density. More clarification of the novelty in the proposed approach is needed as well as how it compares to the state of the art and what has already been covered in literature.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The IPM topology presented is not novel. A current density for up to 42 A_{rms}/mm^2 seems $_{to}$ be assumed and this is more than 2X higher compared to the state of the art. There was not enough information about how such a significant increase can be accomplished. The system voltage and flux-weakening capability has also to be taken into consideration. Also, if higher speed is assumed, the mass and efficiency of any additional gearing should be included.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

There seems to be some collaboration, but more information should be provided.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The novelty of the proposed approach needs to be the focus of future research. Based on what was presented, it is not very clear that the proposed approach can lead to a practical solution to meet the DOE's targets. More details and analysis are needed to build more confidence in the proposed approach.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project tries to pursue few technologies that are relevant, but the novelty and expected performance improvement are not very clear.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources are sufficient.

Presentation Number: elt251
Presentation Title: Device- and System-Level Thermal Packaging for Electric-Drive Technologies
Principal Investigator: Yogendra Joshi (Georgia Institute of Technology)

Presenter

Yogendra Joshi, Georgia Institute of Technology

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

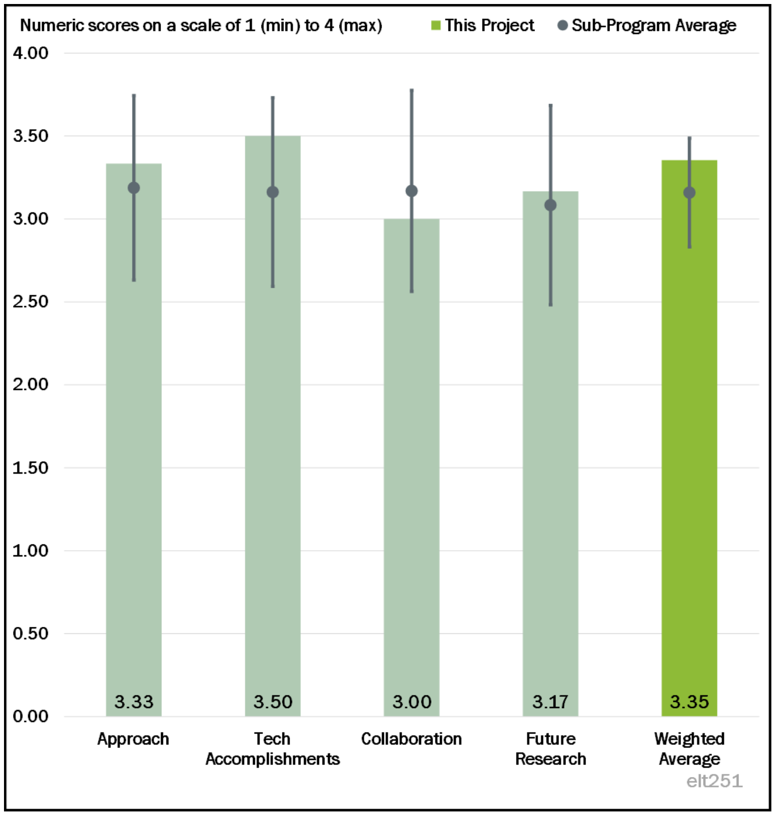

Figure 4-51 - Presentation Number: elt251 Presentation Title: Device- and System-Level Thermal Packaging for Electric-Drive Technologies Principal Investigator: Yogendra Joshi (Georgia Institute of Technology)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This novel approach to dissipate heat looks promising. Combination of simulation and experiment is appropriate to doing proof of concept.

Reviewer 2:

The reviewer found this to be a good approach and methodology.

Reviewer 3:

The proposed use of metal foam and transient liquid phase (TLP) are interesting approaches to electric drive system thermal management and packaging.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

CFD heat transfer modeling of the cold plates with metal foam, 500 W/cm^2 heat flux removal, and exploration of bonding materials via TLP are all excellent advances in the area of electric drive thermal management optimization.

Reviewer 2:

This project just started, but it is good.

Reviewer 3:
The correlation between computational and experimental results looks very good for power inverter module metal foam. Reduced order motor thermal model looks like a good time saver.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaborations with NREL, ORNL, and SUNY Poly are all going well.

Reviewer 2:
There is good collaboration between government laboratories and academic researchers. Have the researchers been able to attract industry collaboration? The reviewer was under the (possibly mistaken?) impression SiC devices are available today.

Reviewer 3:
The reviewer did not see much collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
This is a very important project to understand the thermal properties of an EV drive.

Reviewer 2:
Future work steps are logical next steps for this work.

Reviewer 3:
The FY 2020 and 2021 objectives of thermal packaging and electric motor thermal management with various sub-tasks as listed on Slide 25 are well structured and appear quite promising.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project investigates novel techniques to improve power electronics heat transfer. This is critical to meeting the power density targets set by DOE VTO.

Reviewer 2:
This reviewer indicated that thermal is important.

Reviewer 3:
Optimal efficient thermal management is a key enabler for the DOE stated objective of creating a 33 kW/L electric drive system.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The FY 2020 budget of $300,000 is adequate for the planned research tasks.

Reviewer 2:
The project is on time with the given budget.

Reviewer 3:
It seemed to the reviewer like enough of the resources have been allocated.

Presentation Number: elt252
Presentation Title: Wound-Field Synchronous Machine-System Integration toward Increased Power Density and Commercialization
Principal Investigator: Lakshmi Iyer (Magma Services of America, Inc.)

Presenter

Lakshmi Iyer, Magma Services of America, Inc.

Reviewer Sample Size

A total of one reviewer evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

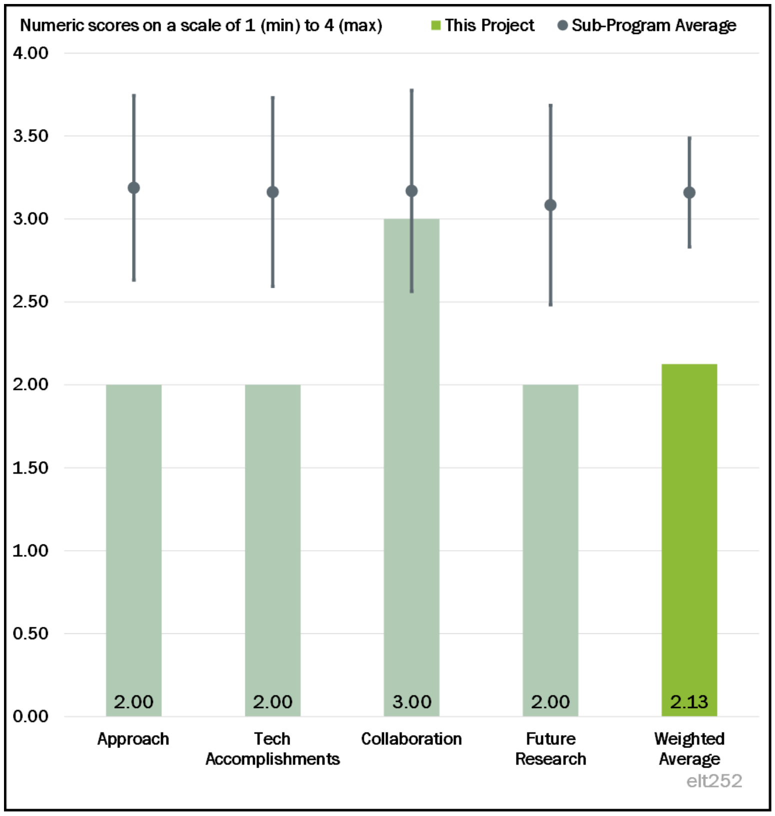

Figure 4-52 - Presentation Number: elt252 Presentation Title: Wound-Field Synchronous Machine-System Integration toward Increased Power Density and Commercialization Principal Investigator: Lakshmi Iyer (Magma Services of America, Inc.)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The novelty in the project is not very clear. The presented stator thermal management is fairly standard and there was no information shared regarding rotor thermal management. Regarding the optimization and the rotor excitation, there is significant overlap with other previously and currently funded projects by the DOE. It is not clear that the proposed approach can lead to eight-fold improvement in power density.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The thermal management scheme presented does not address the rotor cooling, which can be more challenging compared to the stator, and even the proposed stator cooling scheme does not justify significant increase in power density. More analysis and details are needed.

Regarding the optimization results, it is not clear how the presented designs compare to the DOE targets. The key curve that shows efficiency versus torque is not sufficient.

Regarding the rotor excitation, it is not clear if there is any novelty there or the approach is leveraged from previous developments. This needs to be clarified.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There seems to be good collaboration between the three involved organizations.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
More analysis and details are needed to justify the approach and build confidence that there is a realistic path to meeting the DOE targets.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is relevant, but more information is needed to better assess the approach and the progress made.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources are sufficient.

Presentation Number: elt253
Presentation Title: Motor with Advanced Concepts for High-Power Density and Integrated Cooling for Efficiency Machine
Principal Investigator: Jagadeesh Tangudu (United Technologies Research Center)

Presenter

Jagadeesh Tangudu, United Technologies Research Center

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

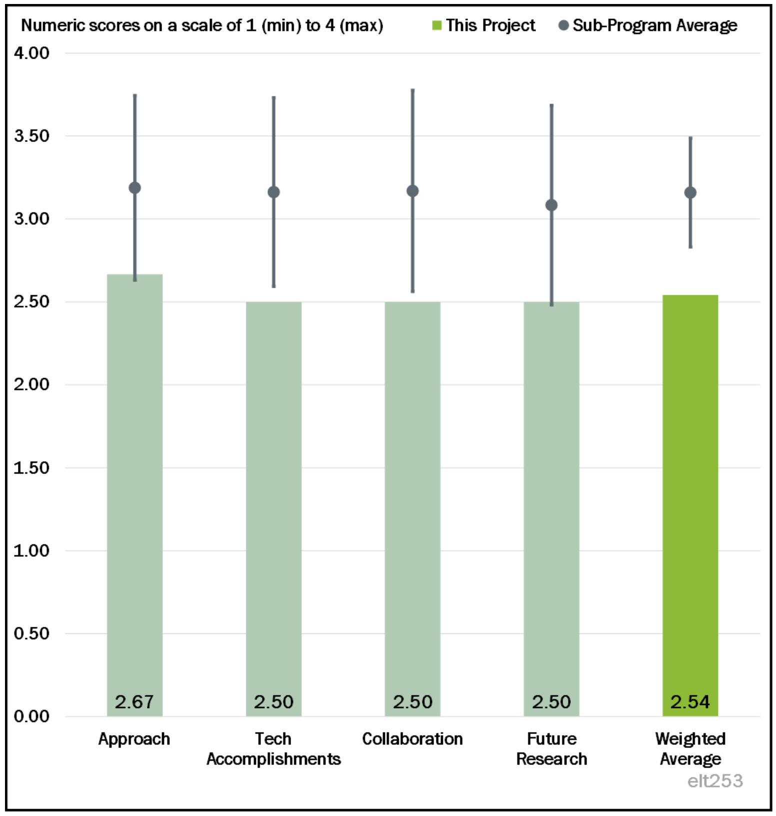

Figure 4-53 - Presentation Number: elt253 Presentation Title: Motor with Advanced Concepts for High-Power Density and Integrated Cooling for Efficiency Machine Principal Investigator: Jagadeesh Tangudu (United Technologies Research Center)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The approach to the project is sound. Technical barriers are being addressed adequately.

Reviewer 2:
The project is in early stage with technical work starting at the beginning of the year. The organization of the project seems appropriate. The PI and the team have adequate background to address all tasks. The major thermal and electromagnetic barriers have been identified, and the project plan appears able to address them.

Reviewer 3:
There are no clear novel technologies proposed to meet the eight-fold improvement in power density. There is not enough information to evaluate the in-slot cooling. Also, with higher speeds, additional gearing should be evaluated and considered.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Progress is acceptable to date.

Reviewer 2:
The project seems to be at a relatively early stage and since the results presented are in per unit (PU), it is hard to assess the extent of the progress made. Even on PU basis, it is not clear that there is a path to meet the eight-fold target.

Reviewer 3:
At this early point in the project, not enough technical progress has been made to evaluate.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There seem to be proper collaboration and coordination among team members.

Reviewer 2:
The project is a seedling and thus a small team is appropriate. The collaboration with John Deere for application specifications is appropriate.

Reviewer 3:
There seems to be no collaboration at the moment outside the sponsoring organization.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Proposed future work is well aligned and planned, per the project objectives.

Reviewer 2:
The novelty, especially in comparison to the state of the- art, should be clarified.

Reviewer 3:
The project has a detailed schedule with appropriate phases and decision points for an effort of this scope. One risk that is not explicitly addressed is the sensitivity of the motor performance to variation in material properties. This risk may be significant for less well-characterized materials, such as high-Si low-loss electrical steels and additively manufactured plastics. The reviewer encouraged the team to send ring cores of the electrical to an independent testing laboratory to verify the core loss and B-H curves. The reviewer also encouraged the team to send additively manufactured plastic coupons out for testing of thermal conductivity and thermal aging tests.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is relevant and well aligned with DOE objectives in 2025.

Reviewer 2:
The project is relevant, but the extent of performance improvement is not clear.

Reviewer 3:
The project is appropriately focused on meeting the Electric Traction Drive Systems performance targets.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources seem to be adequate.

Reviewer 2:
Resources are sufficient.

Reviewer 3:
The project appears to have sufficient resources within the project team to complete the milestones. The PI should, however, indicate if Raytheon is going to build the sectional stator prototype itself or sub-contract it to a vendor.

Presentation Number: elt254
Presentation Title: Ultra-High Speed, High-Temperature Motor
Principal Investigator: Joseph Lyding (University of Illinois at Urbana-Champaign)

Presenter

Faraz Arastu, University of Illinois at Urbana-Champaign

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 33% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

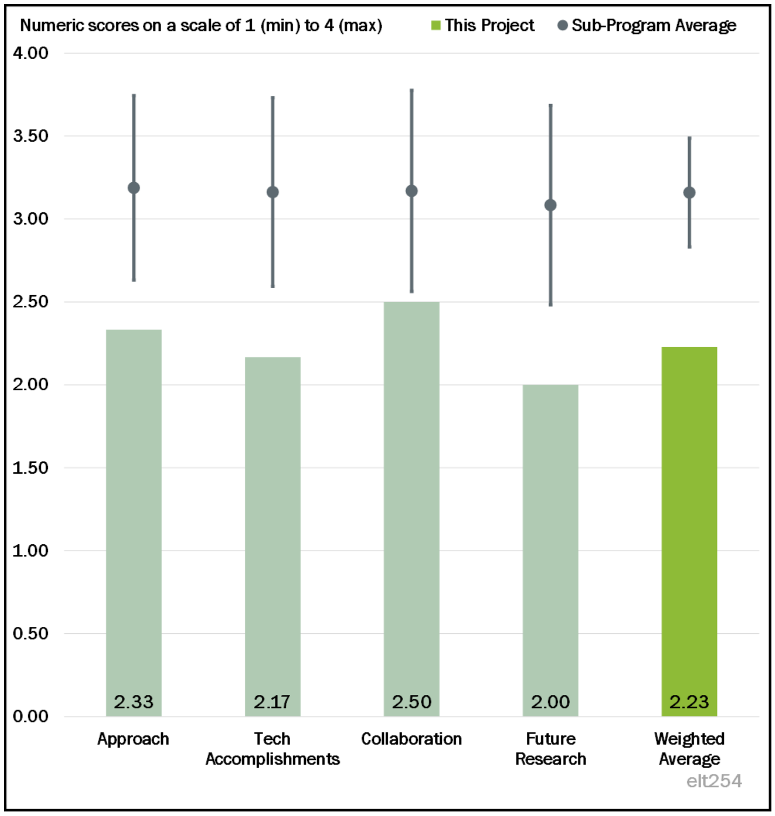

Figure 4-54 - Presentation Number: elt254 Presentation Title: Ultra-High Speed, High-Temperature Motor Principal Investigator: Joseph Lyding (University of Illinois at Urbana-Champaign)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project has just started and early experimental work has been completed on the insulation and magnetic materials. Dielectric test data are presented on the insulation, and a solenoid prototype and soft magnetic composite stator have been shown. However, it is not stated what other thermal, electrical, magnetic, and mechanical properties must be met to enable the materials to operate in a motor with the stated performance targets (125 kW, 50 kW/L, and 60,000 revolutions per minute).

Reviewer 2:

Even though high-temperature insulation can enable higher power density, there are several issues that need clarification:

- The focus seems to be on the wire insulation. What about the other components of the insulation system including slot liner, phase separator and (potentially) vacuum pressure impregnation resin?
- Higher temperature leads to lower efficiency, which can have significant impact on performance. This needs to be quantified.
- The proposed ultra-high speed is not practical for a motor of that size. Any additional gearing needed has to be evaluated and taken into consideration. Also, analysis and evaluation of the bearings has to be performed.

Reviewer 3:
Operating the motor at very high speeds can reduce the motor volume to deliver the same power. This can help with cost reduction. However, at high speed operation, there are several issues:

- Regarding the mechanical strength of the rotor and stator material, what is the tensile strength and yield strength of the soft magnetic composites (SMC)] used in the rotor and stator?
- With respect to the core loss versus frequency, SMCs might have better core loss at high frequency. However, how do the flux density and magnetic field strength (B-H) characteristics and the core loss versus frequency compare for the standard electrical steel used in traction application versus SMC material used in this project? If the B of the SMC material is relatively lower when compared to the electrical steel, then more current is needed to get the same torque.
- How does the resistance vary with temperature and what is the Cu loss at various regions of the machine? The high temperature operation is going to create very high losses. How is this heat (due to the loss) going to be rejected? If there is an enhanced cooling system, then what is the cost of that cooling system? If the cooling system is going to be lot costlier, it can go against the DOE targets.
- What kind of inverter is planned in this project? Is it WBG-based? If so, what is the switching frequency? If the switching frequency is very high, how are the dv/dt and EMI issues addressed in this project?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Only limited test data are presented and no calculations are presented showing how the materials will enable a motor with the stated performance targets are being met. The relevance of the solenoid test, as an alternative to a motor test, to assess the performance of the insulation is not clear.

Reviewer 2:
A test stand and a small motor prototype have been built. However, a lot of progress is expected to happen later this year, as per the plan outlined. The team's response to the above concerns can help to evaluate the project better.

Reviewer 3:
The reviewer referenced prior comments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
John Deere is part of the project team, but their contribution to the project is not well explained.

Reviewer 2:
Collaboration is not very evident.

Reviewer 3:
The second project partner (John Deere) is yet to show their contributions, as their tasks do not start until later this year. The team is well equipped.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
More quantification of the impact of the new materials on machine performance has to be performed. The impact of higher temperatures on efficiency has to be quantified. The proposed high-speed has to be proven to be practical.

Reviewer 2:
The plan to meet the project objectives is not well defined. The plan to develop the electromagnetic, thermal, and mechanical design of the motor is not presented. Go/no-go decisions points are not identified. The risks and mitigation plans are not identified. The scaled-up manufacturing capacity for the new materials is not demonstrated.

Reviewer 3:
Some of the concerns below have to be addressed at some stage of the project. This will help in realizing the proposed technology and also to check the go/no-go decision.

- Regarding the mechanical strength of the rotor and stator material, what is the tensile strength and yield strength of the SMC used in the rotor and stator?
- With respect to the core loss versus frequency, SMCs might have better core loss at high frequency. However, how do the B-H characteristics and the core loss versus frequency compare for the standard electrical steel used in traction application versus SMC material used in this project? If tB of the SMC material is relatively lower when compared to the electrical steel, then more current is needed to get the same torque.
- How does the resistance vary with temperature and what is the Cu loss at various regions of the machine? The high-temperature operation is going to create very high losses. How is this heat (due to the loss) going to be rejected? If there is an enhanced cooling system, then what is the cost of that cooling system? If the cooling system is going to be lot costlier, it can go against the DOE targets.
- What kind of inverter is planned in this project? Is it WBG-based? If so, what is the switching frequency? If the switching frequency is very high, how are the dv/dt and EMI issues addressed in this project?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Novel materials are helpful, but there are concerns about practicality.

Reviewer 2:
Yes, this project meets the DOE objectives for high-speed motors operating at high temperatures.

Reviewer 3:
High-speed machines can increase the power density while reducing the volume and reducing the cost. All of these are important targets that are well aligned with what DOE is seeking.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources are sufficient.

Reviewer 2:
The team has experienced personnel to deliver the tasks outlined in this project.

Reviewer 3:
The scaled-up manufacturing capacity for the new materials is not identified. The testing capability and performance metrics that need to be met are not specified.

Reviewer 4:

Presentation Number: elt255
Presentation Title: Cost-Effective, Rare-Earth-Free, Flux-Doubling, Torque-Doubling, Increased Power Density Traction Motor with Near-Zero Open-Circuit Back-Electromagnetic Field and No-Cogging Torque
Principal Investigator: Soma Essakiappan (University of North Carolina at Charlotte)

Presenter

Soma Essakiappan, University of North Carolina at Charlotte

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

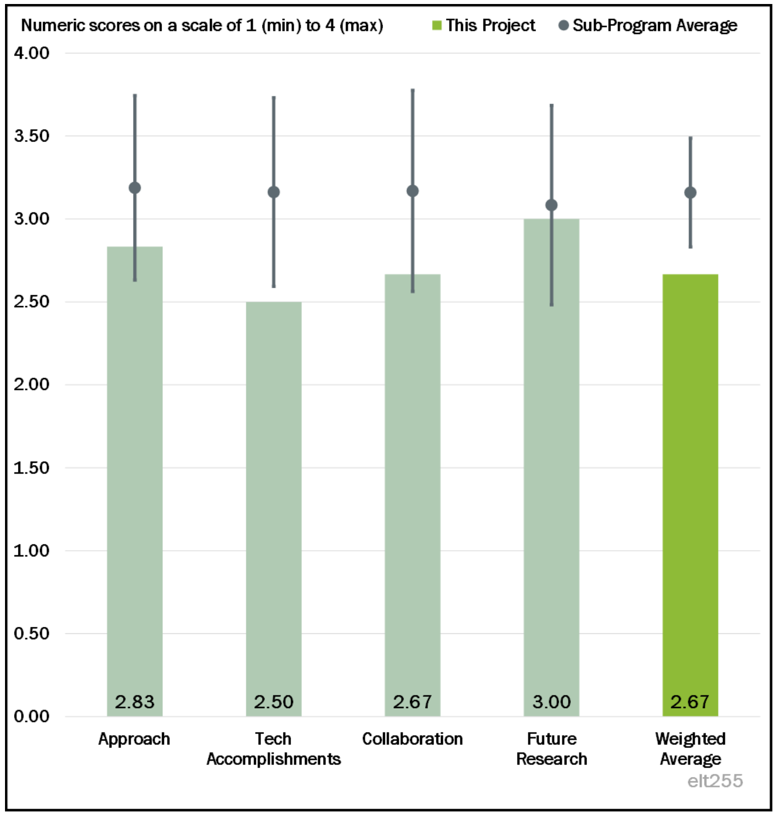

Figure 4-55 - Presentation Number: elt255 Presentation Title: Cost-Effective, Rare-Earth-Free, Flux-Doubling, Torque-Doubling, Increased Power Density Traction Motor with Near-Zero Open-Circuit Back-Electromagnetic Field and No-Cogging Torque Principal Investigator: Soma Essakiappan (University of North Carolina at Charlotte)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project is in its first year of operation. The project approach is comprehensive and seems appropriate for the new technologies being introduced (the high-speed motor with a novel topology with advanced cooling methods).

Reviewer 2:

It was unclear to the reviewer not only if the proposed motor topology is novel or building upon previously developed technology but also why the proposed motor topology can achieve significant improvement in power density. The proposed topology has some analogy to flux-switching machines and seem to be a high reluctance topology, so it is difficult to see from where the power density improvement is coming.

Reviewer 3:

A new concept has been proposed on the motor technology by moving the magnets from the rotor to the stator. It has been claimed that there is flux doubling, torque double, and an eight-fold increase in power density. However, even the simulation results have not been presented to prove the claim.

The reviewer proposed considering an IPM motor used in traction application (for example, the Bolt motor). If a comparison is made with the same stator diameter and stack length, with the same voltage and current inputs, how is it possible to double the torque? Also, when the windings and magnets are placed in the stator, it is definitely going to over saturate the stator lamination (we have to consider the same stator diameter when we compare). In that scenario, the losses are very high and the torque drops.

When the torque is doubled, that means the no load back electromagnetic force (EMF) increases by the same scale. That implies the base speed is reduced by half. However, the claim is a threefold increase in base speed while doubling the torque at the same time. This claim is contradictory.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project has met the objectives it had planned for the early tasks but is not yet advanced enough for a full evaluation.

Reviewer 2:
The reviewer made the following observations:

- The optimization results showing losses versus size and power density are not very clear. More details about how the optimization was done and what assumptions went into it should be included.
- Since the windings are effectively directly exposed to the airgap harmonics, more details about winding AC losses should be included.
- More details about torque ripple should be included.
- A 3:1 constant power speed range might not be sufficient. Some traction applications require up to 5:1.
- The proposed motor stator topology is fairly complicated and will be difficult to mass produce with the required tolerances while also maintaining the stator roundness.

Reviewer 3:
This project has some claims without any proper justification or technical backing. No information is provided regarding the motor dimensions, DC input voltage, maximum RMS phase current, FEA simulation results on the speed-torque characteristics, or efficiency maps. The most important aspect is there is no evidence of how this machine can double the flux and torque at the same time increasing the power density by eight-fold.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team appears to have all of the capabilities needed to complete the project. The roles of each team member are well defined. The contributions of each team member to the project goals are well explained.

Reviewer 2:
There seems to be reasonable collaboration.

Reviewer 3:
QM Power has some experience with this motor technology. But sufficient technical evidence is lacking regarding power density improvement and cost reduction.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed work is reasonable but previously mentioned questions need to be addressed.

Reviewer 2:
The project plan is well structured and has appropriate go/no-go decision points. The major barriers to progress have been identified. The risks and mitigation plans are adequately explained.

Reviewer 3:
The project may showcase a motor-inverter system capable of delivering certain torque and power. However, is it really going to have the power density improvement and cost reduction? A baseline has to be established when a claim like this is made. Without simulation and dynamometer test results, and comparison with state-of-the-art IPM machine having the same dimensions, voltage constraints, current constraints and cooling strategy, it is hard to prove that the target metrics have been met.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project directly addresses the targets on the Electrical and Electronics Technical Team Roadmap.

Reviewer 2:
The project is relevant, but the approach needs more clarification and supporting analysis.

Reviewer 3:
As pointed out earlier, this project claims superior power density with significant cost reduction. However, unless it is supported with sufficient simulation data and dynamometer test data, and compared with a current baseline motor (like Tesla or a Bolt motor), it cannot be said that this project supports the DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources are sufficient.

Reviewer 2:
The resources the project have seem appropriate to meet the stated milestones.

Reviewer 3:
It is feasible that the project may deliver a motor and inverter. Is it really going to outperform the current state-of-the-art traction machines? That is the big question.

Presentation Number: elt256
Presentation Title: Amorphous Metal Ribbons and Metal Amorphous Nanocomposite Materials Enabled High-Power Density Vehicle Motor Applications
Principal Investigator: Mike McHenry (Carnegie Mellon University)

Presenter

Mike McHenry, Carnegie Mellon University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

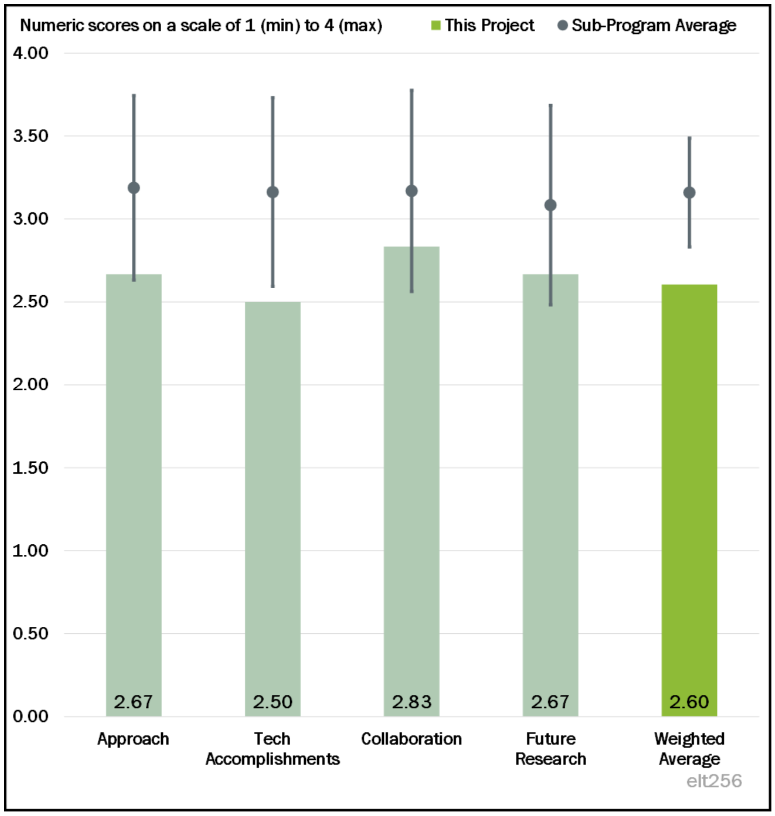

Figure 4-56 - Presentation Number: elt256 Presentation Title: Amorphous Metal Ribbons and Metal Amorphous Nanocomposite Materials Enabled High-Power Density Vehicle Motor Applications Principal Investigator: Mike McHenry (Carnegie Mellon University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach to the project is sound. Technical barriers are being addressed adequately.

Reviewer 2:

It is not clear what the bases are for choosing the presented 2.5 kW topology. It is not clear that the proposed approach can lead to an eight-fold increase in power density based on the state of the art of traction motors.

Reviewer 3:

At the time the review slides were written, the project had been in operation for a few months. The approach consists of comparing the performance of a new metal-amorphous nanocomposite alloy to the performance of a commercial iron-cobalt (FeCo)-Metglas, Inc. and conventional electrical steel. The benchmark will be done in a flux switching motor topology that enables high power density with lower coercivity magnets. The comparison will include FEA simulations of the electromagnetic, thermal, and mechanical performance of the motor, as well as evaluation of motor components built with the new materials. The project scope does not appear to include testing of a completed motor. This approach is sufficient to meet the goal of benchmarking the performance of new soft magnetic materials to the degree needed to assess if they should be developed to a higher technology readiness level.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Progress is acceptable to date.

Reviewer 2:
The technical accomplishments meet expectations for the initial stages of the project. All the required resources appear to have been retained, and the initial work is systematically evaluating material performance in an existing motor design. Initial design studies of a novel flux switching design appear to have been completed, and initial casting trials and characterization of the new soft magnetic alloy have been completed.

Reviewer 3:
The presented comparison between the 2.5 kW and 20 kW designs is confusing. Since there is a significant difference in the slot fill factor as well as the assumed current density (which is mainly dependent on cooling), it is not clear what the contribution is of the expected improvement in material properties. Also, 20 kW does not represent the typical rating of a traction motor.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There seems to be proper collaboration and coordination among team members.

Reviewer 2:
There is reasonable level of collaboration.

Reviewer 3:
The team is well coordinated, and the roles and responsibilities of each team member have been well defined.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future work is well aligned and planned, per the project objectives.

Reviewer 2:
A practical baseline of a traction motor should be used moving forward.

Reviewer 3:
The proposed future research is effectively planned to meet the goals of the project. The evaluation of the FeCo-Metglas alloy adequately mitigates the risk of unforeseen problems arising during development of the new metal-amorphous nanocomposite alloy. The manufacturability of the new alloy and the new motor design will be considered. To be most impactful, some consideration should be given to the interface between the novel motor design and the balance of sub-systems in an EV, such as what kind of power supply and motor controller will be needed. What voltage will the motor operate at? Will conventional bearings and thermal management systems be usable, or will new sub-systems need to be designed? Finally, the capacity of the supply chain to produce the new alloy should be calculated in order to determine what fraction of the EV market can be addressed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is relevant and well aligned with DOE objectives in 2025.

Reviewer 2:
The project is relevant, but the level of expected performance improvement is not very clear.

Reviewer 3:
The project supports the overall objectives because its goal is focused on enabling higher performance motors that can meet the DOE roadmap's performance targets, as well as minimizing the use of HRE elements like Dy.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources seem to be adequate.

Reviewer 2:
Resources are sufficient.

Reviewer 3:
The resources of the project team are adequate to meet the goals of the project.

Presentation Number: elt257
Presentation Title: Directed Electric Charging of Transportation using eXtreme Fast Charging (XFC) (DIRECT XFC)
Principal Investigator: Tim Pennington (Idaho National Laboratory)

Presenter

Tim Pennington, Idaho National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

67% of reviewers indicated that the project was relevant to current DOE objectives, 33% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

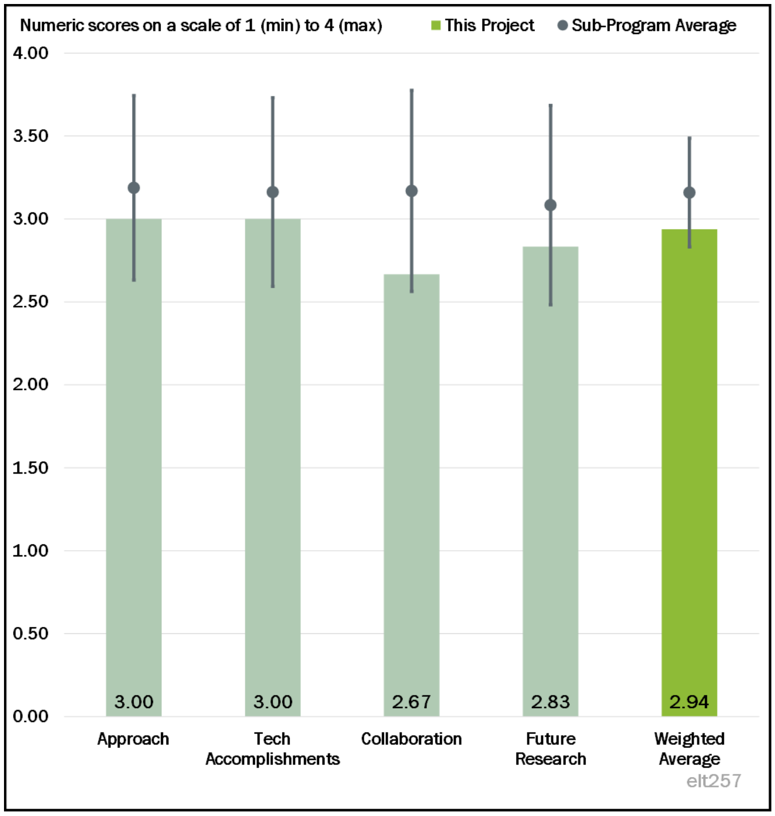

Figure 4-57 - Presentation Number: elt257 Presentation Title: Directed Electric Charging of Transportation using eXtreme Fast Charging (XFC) (DIRECT XFC) Principal Investigator: Tim Pennington (Idaho National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This approach is excellent because it considers the baseline with no controls in the system and sequentially adds stationary storage, communication, and reservations for evaluation of result combinations. This also includes both AC and DC charging and fleet and private EVs.

Reviewer 2:

The plan seems well thought out. It will be critical for the project team to establish the baseline case of unmanaged charging in order to fully understand value and impact of controlled scenarios. It was not clear if/how driver behavior was going to be assessed in the project flow—that is, what if drivers are reluctant to be rerouted to other locations as a means of optimization? To some extent, the valuation exercise planned in task 1.4 may help address this by at least providing some baseline value as seen from the driver's perspective. The concern would be that even with a clear value to the driver, consumers may not choose a low-cost scenario based on inconvenience issues. Will the project address driver behavior as a counter to the most "sensible" control scheme?

For grid impacts, it was not clear if the OpenDSS simulations would be used to calculate potential cost impacts to distribution for the unmanaged case and then compare a simple grid upgrades path as a mitigation strategy to the cost of a fully managed system.

The project approach relies on a control system that must span multiple charging locations—having a regional component. It was not clear how, in a competitive market, where some portion of charging stations might fall outside this "controlled" system of chargers, will be accounted for in the work. It was also not clear if the project would attempt to account for competitive pricing's impact on consumer behavior, where competitive pricing strategies are driven by factors not accounted for in the simulation tools. Might this undermine the optimal scenario for system performance, and can the impact be quantized?

It was not clear from the presentation if the AC level 2 simulation capabilities of Caldera™ would be exercised in the project. It was not clear from the presentation if driver behavior related to use of public (XFC) versus lower power public and private charging would be accounted for in modeling efforts. Is there a plan to look at actual driver behavior to inform the Caldera model? Will the impact of site level optimization that is done independently on the regional optimization strategy be studied/simulated? Is all optimization cooperative?

Will results of HIL testing and any limitations encountered be fed back into the Caldera modeling tool to optimize its behavior?

Reviewer 3:

The reviewer provided the following comments:

- The objective is to determine the value of directing when and where EVs will use XFC to minimize cost and grid. The major problem with the approach is that it assumes there is a growing demand for EVs but that does not mean the growth in XFC of such vehicles will be in parallel. It will not be a one-to-one correspondence because XFC will cost more. What is the willingness of the market of EV owners to pay extra for XFC? There was no discussion of that issue—on which this project is predicated.
- The project fails to identify the end-user of the determination made by the modeling. Is the end-user a fleet, individual EV owner, an XFC station owner/operator or an electric utility?
- The assumptions of neither the model nor the modeling scenarios are not well laid out and clear. Whether the model and its results are realistic usually are predicated on the assumptions that go into the model. How realistic are these assumptions? Have the assumptions been tested for realism?
- Of particular primary importance, nobody knows where the future XFC stations will be located. There is no guarantee that they will be evenly distributed across a metropolitan area. There may even be an unforeseen tendency of competitors to cluster because of the effect of real property cost and real property availability.
- Of particular secondary importance is that consumer input seems to be ignored in the model. How much are owners of EVs willing to pay extra for XFC? How many owners of EVs are willing to pay for XFC?
- Of particular tertiary importance, how willing are owners of EVs to drive to an unfamiliar neighborhood or location, perhaps, across town, to XFC their vehicles? It may even take more time than it is worth depending on travel conditions, such as traffic congestion. Or, the XFC station was not on the route the driver already had in mind for his travel that day. A lot of driving involves trip-chaining in which a driver expects to make certain stops in a certain order (buying groceries, going to a medical appointment, picking up dry cleaning, dropping off children, etc.). Was trip-chaining taken into account and the inconvenience imposed on trip-chaining or even normal commuting patterns when a driver is directed to an XFC station out of his way?
- Of next importance is that there is no clear indication about the make-up of EVs covered by this model and their range, their travel patterns (origin, destination). The reviewer questioned the failure to include return-to-base, centralized XFC for utility and municipal fleets, rental cars, etc. The reviewer also questioned the failure to include MD and HD vehicles in the modeling.

- The project team needs to tell the reviewers how the results of the directed charging model will be corroborated against reality, .

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Since this is the first year of the project, the contributions of each lab are clear and complementary to each. The initial operation and approach are clear and seems to be on target.

Reviewer 2:
The team seems to have made good progress on early tasks even with the impact of COVID-19. Accomplishments to date were based on isolated lab efforts.

Reviewer 3:
The results so far only indicate what the model can do and what the model can forecast. There is no way for anyone to determine whether the results of the directed charging model are (rather will be) realistic at all; in other words, there is no way to confirm the model. The reviewer would evaluate technical accomplishments and progress by comparing it to reality or improvement of what is already real.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The labs have variations to their expertise and their contribution is a good match to success of this project.

Reviewer 2:
To date, much of the work completed has been segregated across the project lab teams, requiring minimal cooperation between the participating labs, so it is difficult to assess how well the teams will handle the complex coordination tasks to come later in the project.

Reviewer 3:
No end-user was identified. Not even the local electric power utility was included as a collaborating or cooperating organization. The local metropolitan transportation planning organization, which is required by the U.S. Department of Transportation (DOT) to be involved in approving highway/transit projects for federal funding and collects travel demand data and travel pattern data for different surface modes, was also not included as a collaborating or cooperating organization.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The first-year data are expected to provide results to guide planning of grid usage and benefits of balancing stationary storage needs with communication and reservation requirements to meet EV charging needs.

Reviewer 2:
From the milestone list, it appears the project team has a good plan for addressing their future work. One concern is that project results will not be published until late in 2021, while lessons learned from the effort might benefit near-term system planning and station deployment. Is there any plan to report results prior to the final report to benefit real-world infrastructure deployment?

Reviewer 3:
This project is premature. There are no data on market demand for XFC of EVs, nor are there data on where future XFC locations will tend to be. No data were furnished that use of data on specific travel patterns of EVs was made.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is very relevant since it provides information on how and where to add resources and communication at charging locations.

Reviewer 2:
The project studies optimization strategies that stand to benefit a wide audience of stakeholders. This seems befitting of a DOE sponsored activity.

Reviewer 3:
The PI did not make a case for what is so important about developing this model for directed XFC. Will not having it make any significant difference to society, energy security, fossil fuel consumption, climate change?

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The noted team sizes and schedule seem reasonable. This assessment is also based on progress the project team has shown to date which also seems in line with project plans.

Reviewer 2:
These laboratories have the resources to accomplish this project goals and provide guidance on how to balance the grid and vehicle charging needs.

Reviewer 3:
The reviewer had no comment.

Presentation Number: elt258
Presentation Title: Grid-Enhanced, Mobility-Integrated Network Infrastructures for Extreme Fast Charging (GEMINI-XFC)
Principal Investigator: Matteo Muratori (National Renewable Energy Laboratory)

Presenter

Matteo Muratori, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

67% of reviewers indicated that the project was relevant to current DOE objectives, 33% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

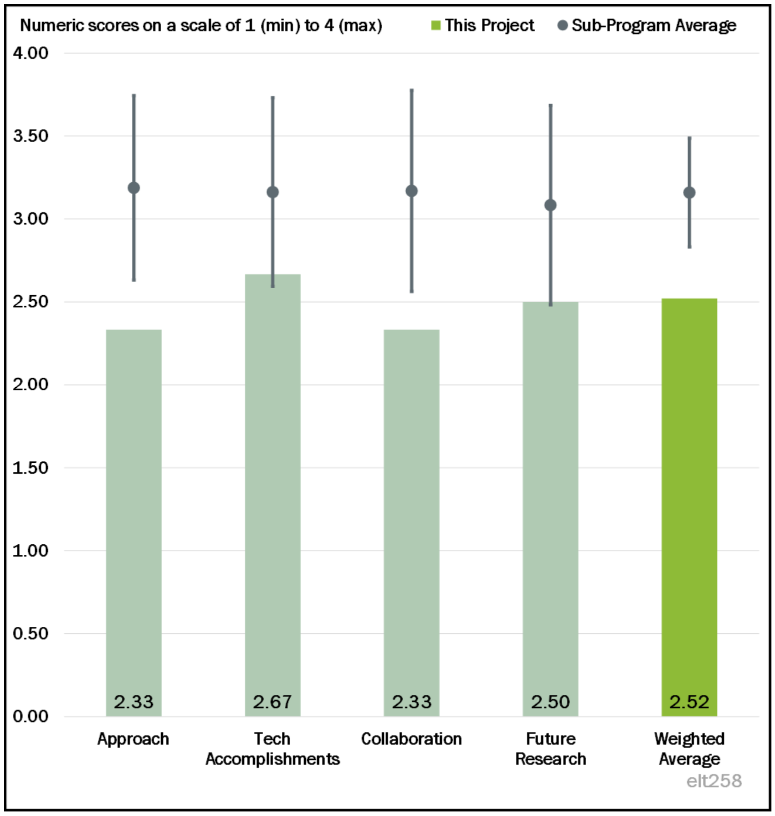

Figure 4-58 - Presentation Number: elt258 Presentation Title: Grid-Enhanced, Mobility-Integrated Network Infrastructures for Extreme Fast Charging (GEMINI-XFC) Principal Investigator: Matteo Muratori (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project goals seem very broad. It was not clear what bounding conditions would be used for the key questions listed on Slide 10—who will optimization benefit? For example, if smart charging can reduce voltage variation from solar production, but requires a control technique that hinders EV drivers with a high level of inconvenience, how would driver behavior be accounted for?

The presentation did not mention engagement with utilities that serve the area being simulated. It seems like this effort would benefit from utility engagement. Will grid scenarios be reviewed by utilities?

The models planned have broad coverage and very complex inputs. How will the models be vetted, given the goal of covering disruptive scenarios in the transportation field? It was not clear that there is a baseline case that can be simulated to test the model's outputs.

Reviewer 2:

The project focus is on larger vehicles because they do require XFC. This also depends on the usage because if the vehicles are only operated at one shift, rather than continuous, slower fast charge should be considered.

Reviewer 3:
It is unsatisfactory that there were absolutely no slides indicating the explicit goals or objectives of this project. There was an approach slide, but approach to what? Widespread electrification is mentioned but for what (as if there was no electrification) already in-place?

Second, any and all modeling requires making assumptions. The assumptions underlying the modeling were not laid out. There was no mention of whether any kind of reality check was performed on those assumptions. The project team's assumptions include high EV adoption, the make-up of the kinds of EVs assumed in the model (their range), travel patterns (origin and destination) of EVs, how many EV owner/operators would be willing to pay more for the higher cost of XFC, distribution of XFC EV charging stations, and where the XFC stations are to be located (if as claimed, they will be in downtown for ride-hailing EVs, land value will be very expensive—how is that taken into account?).

Lastly, when the model runs from the computer produce results, how are those results going to be validated and verified? How realistic are the results?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project is in the initial stage, so more time is needed to see how the various approaches are combined and used.

Reviewer 2:
Progress noted seems reasonable but is very preliminary (3-year project that has only been underway for a few months). For that reason, it is difficult to assess the longer-term efficacy of the project.

Reviewer 3:
The reviewer asked how progress or technical accomplishments can be measured where there are no goals or objectives explicitly stated. It would be unfair, impartial, and non-objective of the reviewer to use implied goals and objectives.

Moreover, what has been presented as technical accomplishments are really what the model can do and forecast in different limited scenarios. The reviewer questioned how model results could be validated.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project does not appear to have progressed to the phase where integration of the simulation tools from NREL and LBNL will be merged into a system. Based on this, it is difficult to address the status of collaboration across the project teams.

Reviewer 2:
The project appears to be well organized, but specific items for each team is still not clear in this early stage of completion.

Reviewer 3:
No end-users were identified. The reviewer questions the project value without an end user identified. No collaborating or cooperating organizations outside themselves and DOE were specified. The reviewer was disappointed because the reviewer would have expected as critical collaborating or cooperating organizations: the local electric utility, which is Pacific Gas and Electric (P&GE) and the Metropolitan Transportation Commission (MTC) for the nine-county San Francisco Bay area. PG&E is critical because it is the utility that has the monopoly over the distribution of electric power in the San Francisco Bay area, over which the model is being applied. MTC is critical because it is the federally and state-recognized metropolitan transportation

planning organization involved in recommending all local highway and transit projects for federal funding. The MTC is responsible for collecting data and forecasting transportation patterns including origin and destination of trips by mode and frequency. While the PI did not know the answer as to whether MTC provided input to the model that is the subject of the project research and a staff member had said he did have contact with MTC, the fact that MTC is not a collaborator and the slides do not mention MTC input made the reviewer skeptical about the extent the local experts on data on travel patterns and travel demand were consulted and asked to cooperate on a project relying on important local travel data.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The specific focus of high-power charging and within the area of San Francisco should be expandable to other areas and a broader range of vehicle charging power levels. More time in this project will lead to a better conclusion on future research potentials.

Reviewer 2:
With broad goals, complex models that consider future looking (and disruptive) scenarios, and the need to integrate output from the models into a coherent picture, a key challenge will be to develop baseline scenarios that allow assessing model efficacy. How will researchers know that the Transportation Energy & Mobility Pathway Options (TEMPO) is providing valid results? This question becomes even more complex when the various models are combined to assess regional results. It was not clear from presentation how researchers will validate models to show that results presented from disruptive scenarios will be valid.

Reviewer 3:
This project is premature. There are no market data on the numbers or proportion of owner and operators of EVs who would pay for XFC knowing that it costs more than conventional charging. There are no data on where and how many XFC stations will be located. The reviewer was skeptical that the project actually made use of data on travel patterns (origin and destination) and travel demand by mode and frequency from the MTC for the nine-county San Francisco Bay area for input into the project's model.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Understanding regional impacts of disruptive changes in transportation systems is vital to enable sensible future planning for utilities, cities, and other stakeholders in the transportation field. Advancing understanding in this area seems befitting of a DOE project.

Reviewer 2:
While passenger cars need XFC, that usage may be less than once a month so the timing of this needs to be considered.

Reviewer 3:
The project team does not make a case for the relevance of this project to DOE objectives. The team needs to answer the question: what is so important about developing this model—will not having it make any significant difference to society, energy security, fossil fuel consumption, climate change?

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Because the project is very "early-in" it is difficult to assess team sufficiency. Reasonable progress has been made since project inception which leads me to rate this as sufficient.

Reviewer 2:
The predictive part of when EVs need to be charged is not included at this point, but there may be data available from other projects and used in this project as needed.

Reviewer 3:
This reviewer had no comment.

Presentation Number: elt259
Presentation Title: Development and Commercialization of Heavy-Duty Battery Electric Trucks Under Diverse Climate Conditions
Principal Investigator: Marcus Malinosky (Daimler Trucks North America)

Presenter

Marcus Malinosky, Daimler Trucks North America

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

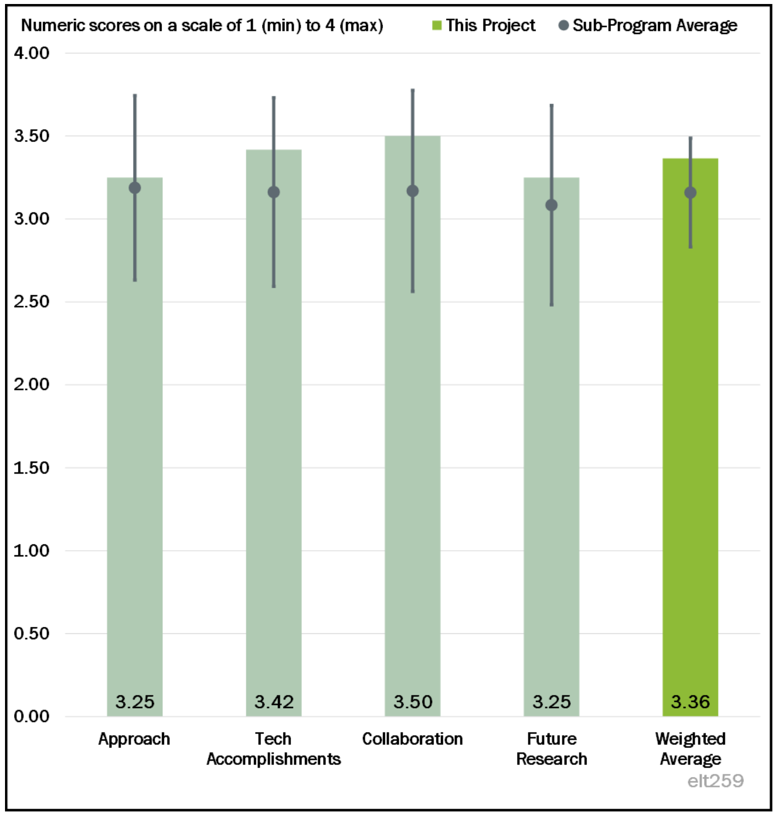

Figure 4-59 - Presentation Number: elt259 Presentation Title: Development and Commercialization of Heavy-Duty Battery Electric Trucks Under Diverse Climate Conditions Principal Investigator: Marcus Malinosky

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project is leveraging global design, engineering, sourcing, and vertically integrated production capabilities to quickly achieve economies of scale and reduce product costs. Through a “co-creation” approach with fleet partners, the project will collect operator feedback and determine best practices for continuous improvement.

Reviewer 2:

In spite of delays due to the COVID-19 outbreak, the project appears on track from a timeline that is relatively aggressive.

Reviewer 3:

The barriers to short-term progress have been listed related to the manufacture, delivery, and testing of the B sample units at Meier and UPS. However, barriers that are no doubt already recognized for C and D samples have not been listed. For example, the presentation implies that the powertrain design may change from using wheel motors to an e-axle arrangement (reduction in motors). This kind of powertrain change may present some barriers not seen in previous samples. The presentation also states a goal of achieving 2.0 kWh/mile to increase range with the battery pack—this seems like a very tall order, given the likely duty cycle of the two fleet partners. The reviewer assumed there are significant barriers related to that goal.

Reviewer 4:
It is very difficult to do an evaluation with so little information. The reviewer would have liked to see information about how many trucks, what type and size of battery, what types of duty cycles proposed, and how the designs were/will be decided. This difficulty is at least in part caused by the format and content requested by the system. However, the reviewer did not think it is very useful. Additionally, note the title mentions weather but the presentation does not.

Reviewer 5:
The project is being executed by a highly capable organization with excellent partners. Good product development processes are being used with critical milestones clearly laid out. The reviewer's main concern was with respect to details on customer requirements for the target segment. Other than a 250-mile range, no customer requirements including charging time or weight are specified. While it is possible that many routes could be fulfilled with a 250-mile capable BEV, customers may use the same truck on multiple back to back routes which limits charging times.

Reviewer 6:
Daimler Trucks North America LLC (DTNA) E-Mobility Group (EMG) is leveraging global design, engineering, sourcing and vertically integrated production capabilities to quickly achieve economies of scale and reduce product costs. Through a "co-creation" approach with fleet partners, DTNA EMG will collect operator feedback and determine best practices for continuous improvement. Changing eMachine for increased efficiency will allow the project performer to overcome barrier of range anxiety.

This approach will allow commercialization of battery powered electric trucks, preferably adopted by fleet owners such as UPS.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The vehicle mule is together and all targets appear to be on track in spite of COVID-19 delays. The B-sample build was completed in April of 2020 and testing is in progress.

Reviewer 2:
It is encouraging that B sample delivery and testing are underway as they will provide invaluable input to the remainder of the project. Other completed and in-process steps appear to show good progress toward achieving objectives.

Reviewer 3:
The project team has made significant progress and achieved critical project milestones for Phase 1a: Research, Design, Building and Commissioning—Vehicle Design and Specifications, including completion of the B-sample build.

Reviewer 4:
The team has accomplished much in a very short time, including the B-sample build and 75% completion of C-sample design documentation. This is highly impressive, given the short time since the project began.

Reviewer 5:
There is quite great progress, as outlined by the PI: The B-sample build was completed April 2020; B-Sample vehicle testing in process; C-Sample vehicle design and integration is in process with approximately 75% of the design documented; C-sample vehicle simulation is ongoing; D-Sample vehicle design is in process; and D-Sample development supplier selection in process.

The project team has made significant progress and achieved critical project milestones for Phase 1a: Research, Design, Building and Commissioning—Vehicle Design and Specifications, including completion of the B-sample build.

Reviewer 6:
The project has just started. Subsequently, the reviewer referenced prior comments and indicated that it is hard to know whether the team is doing a good job. The reviewer would really like to see some information about what different truck versions were included. The presentation includes minimal information.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The team has excellent partner organizations that have demonstrated a commitment to increasing freight efficiency. To date, the bulk of the work is likely to have occurred at DTNA (the prime). Partner participation should increase significantly once testing is under way.

Reviewer 2:
Collaborators are Meijer, UPS, and SCAQMD for various aspects of the project.

Reviewer 3:
Strong fleet partners and SCAQMD is a great agency to work on these types of projects.

Reviewer 4:
The appropriate mix of OEMs in conjunction with testing partners appears well coordinated relative to the current project timelines.

Reviewer 5:
Coordination between Daimler and listed partners looks to be productive and effective. Short term schedule risks have been identified and highlighted.

Reviewer 6:
Once the trucks are built, the team will have very good partners to test them, but the reviewer was not so sure about build, design, and process data.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer noted that future research includes the following: continuing B- Sample vehicle testing; completing C-Sample vehicle design, integration, and simulation; and beginning C-Sample vehicle procurement. In period, the team will also complete D-Sample vehicle development supplier selection and begin D- Sample tooling supplier selection.

Reviewer 2:
The project is aggressive and timelines appear met. However, the reviewer would like to have seen more detail relative to the technology used to address the diverse climate conditions the vehicle will operate under (hot/cold). A number of studies show the issues associated with EV range loss relative to heating, ventilation, and air conditioning requirements. Some technical details in the vehicle design and approach would be appreciated.

Reviewer 3:
The proposed future work is logically laid out. The reviewer's main concern was with respect to time allowed for testing of the hardware and software. C-sample build and go/no-go approval are both shown to occur in the same month (milestones slide). It is also not clear what regulatory approvals are required prior to production release.

Reviewer 4:
The plan outlines the steps and schedule in a logical way, but details of future technical challenges have not been outlined. One objective of the project is to test under diverse climate conditions, but this objective is not reflected in the presentation material. There are a number of diverse climate conditions that will not be demonstrated by Michigan and California climates.

Reviewer 5:
The project aligns very well with field testing of B, C and D samples.

Reviewer 6:
This progress report does not include enough information to enable the reviewer to properly evaluate the work. There is no technical detail provided. So, this reviewer cannot adequately address the questions posed. It was unclear to the reviewer how to ask questions of the poster presenters.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project advances state-of-the-art HD electric truck technologies to full commercialization and provides a platform for the market to reduce maintenance and energy costs, diesel consumption, carbon, nitrogen oxides, particulate matter (PM), and emissions.

Reviewer 2:
The significant testing of vehicles in customer operations and duty cycles is a great way to support overall DOE objectives. This testing should provide invaluable information as electrified vehicles start to be implemented in the marketplace.

Reviewer 3:
Battery-powered vehicle are relevant to DOE VTO goals and objectives.

Reviewer 4:
The goal of reducing petroleum needs requires a reduction across the vehicle spectrum, both LD and HD. This project approaches the HD transportation sector via electrification and if successful is cited to serve the needs of 75% of the marketplace.

Reviewer 5:
This project is accelerating development of BEVs in collaboration with customers. There are no BEVs on the market today from major truck OEMs that meet the needs of 70% of the freight hauling market. While new entrants can be exciting and innovative, many customers want to continue to purchase from OEMs with which they have built a long relationship and where they know what to expect from the service and support network. One concern here is that commercial feasibility (i.e., cost and fleet ROI is not addressed.

Reviewer 6:
All projects aimed at replacing fossil fuel use with electricity are consistent with DOE goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project team has demonstrated excellent use of the available resources to date. The COVID situation will strain all organizations as the team has pointed out. If the team is able to continue to access and leverage global resources, they should be able achieve their milestones as planned.

Reviewer 2:
The project has sufficient resources.

Reviewer 3:
The project appears funded sufficiently to overcome barriers and hit the targets of a relatively aggressive timeline.

Reviewer 4:
At this point, resources appear to be sufficient.

Reviewer 5:
The project has enough funding and resources. The project report looks quite different compared to other DOE VTO-EDT projects.

Reviewer 6:
There is not enough information provided to answer this question meaningfully.

Presentation Number: elt260
Presentation Title: Improving the Freight Productivity of a Heavy-Duty, Battery Electric Truck by Intelligent Energy Management
Principal Investigator: Teresa Taylor (Volvo)

Presenter

Sam McLauglin, Volvo

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

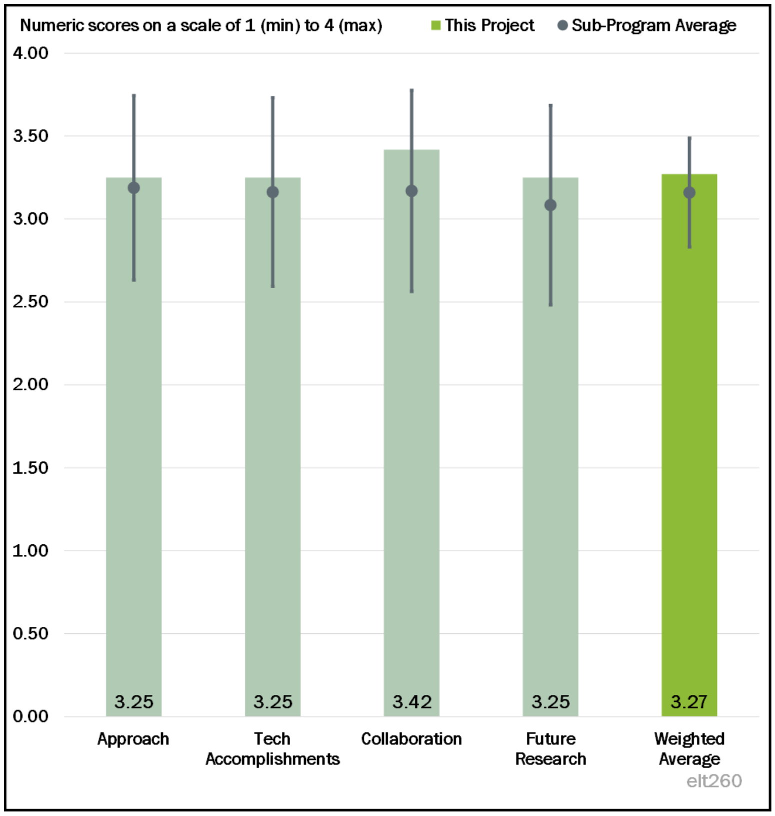

Figure 4-60 - Presentation Number: elt260 Presentation Title: Improving the Freight Productivity of a Heavy-Duty, Battery Electric Truck by Intelligent Energy Management Principal Investigator: Teresa Taylor

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project has a limited, clearly-defined mission that will improve the operating performance of existing electric trucks. The improved efficiency will substantially improve the economics of owning an electric truck. The energy management system (EMS) will reduce the TCO at minimal added cost.

Reviewer 2:

The reviewer observed a solid project approach by understanding fleet partners' baseline operations and establishing project duty cycles. The team is combining a physics-based truck model, battery information, utility demand charges, and database parameters as inputs to a machine learning algorithm that will predict energy use, operational energy cost, and battery performance. The reviewer also noted installing vehicle charging locations at fleet partners and demonstrating intelligent energy management system in daily operations with fleet partners covering both cold- and hot-weather conditions.

Reviewer 3:

The approach of combining real-world usage data and vehicle modeling to suggest the best energy efficient route is reasonable. The machine learning component seems a bit unconvincing.

Reviewer 4:

Although the reported completion percent is only 5% at this time, the reviewer thought the approach is somewhat vague in terms of objectives. The baseline is not well defined, so progress against that baseline would be very hard to measure. In addition, no milestones or tasks were listed for calendar year 2022 in the slides. The claim of achieving 20%–30% in battery driving range would appear to require many improvements in vehicle component integration as well as improvements in the management of vehicle operations. These kinds of improvements in energy consumption are few and far between in today's diesel world.

Reviewer 5:
Conditional route optimization can play a role in energy consumption reduction. The project is relatively early in its stages, so it is difficult to ascertain how much of the physics-based model development, duty cycle development, and systems integration have occurred.

Reviewer 6:
The project is logically laid out with data from multiple vehicles in use at a customer location, and a baseline vehicle has been defined. The only weakness the reviewer saw is if the project were reliant on driver behavior as a significant source of efficiency gains, it will be difficult to assess the real-world effect of those gains. The reviewer did not believe one can assume 100% compliance from drivers as is stated in response to the question on driver behavior.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Work streams are in progress and appear to be on track based on project timing chart.

Reviewer 2:
The project is just getting started, but the project team seems to have made significant progress toward understanding the duty cycles, routes, etc., of the vehicles they will be equipping with EMS.

Reviewer 3:
Accomplishments include the baseline of fleet partners' operations: 10 Vehicles have been identified at Murphy Logistics, and the VIN # information is being collected. Understanding fleet partners' baseline operations and establishing project duty cycles. Physics-based truck model is completed. University of Minnesota has identified all of the model parameters, their descriptions, and current values for the electric truck model.

Reviewer 4:
The project is too early to determine if it is behind schedule or requires additional project management to overcome the inevitable issues.

Reviewer 5:
Progress listed on the milestone chart does not show any completed items in the six or so months since the contract award. The milestone chart does not outline dates within the year that tasks should be completed. No milestones for year 3 are listed.

Reviewer 6:
The project is in the very early stages. Work on the truck model has begun though much of what has occurred to date is planning and analysis. Two quarters feels like a long time to spend characterizing duty cycles for 10 trucks (Accomplishment and Gantt chart from Proposed Future work slides).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
In addition to being led by the truck manufacturer, which is important, the team has two partners that will actually run the trucks in commercial operation. That is good; it is also key that a university was included to deal with the key feature: machine learning.

Reviewer 2:
This reviewer described the team is very strong:

- Volvo (PI)—contract management, project management, and engineering resources for truck operation, data collection and route simulation
- University of Minnesota—vehicle to capture cloud data management, algorithm development, data analytics, and secondary driver display
- Greenlots—electric charging support and installation of chargers
- HEB Companies—fleet testing, operational data, and driver feedback
- Murphy Logistics—fleet testing, operational data, and driver feedback.

Reviewer 3:
Partners are appropriate to meet the project objectives.

Reviewer 4:
A sufficient blend of OEMs, academia, and site partners are available for a proper cold/hot (Minnesota/Texas) demonstration of the technology.

Reviewer 5:
Partners have been identified and the roles seem fairly clear. The specific areas or teams within Volvo are not identified in the presentation.

Reviewer 6:
Duty cycle data have been collected from the fleets and the modeling work by the University of Minnesota has been kicked off indicating that all parties are engaged.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Future plans and research include the following:

- Collecting and analyzing fleet customers' baseline duty cycle
- Creating a baseline database using all collected parameters for chosen duty cycles and deciding representative duty cycles for the project
- Creating the project verification plan
- Placing purchase order for build of truck demonstrator
- Creating physics-based, battery electric truck model
- Creating initial machine learning
- Defining locations for on-route charging
- Determining optimal on-route charging locations for fleets.

Reviewer 2:
The team proposes to get even better supporting information and modeling results before they actually operate the trucks; that means that many of the potential glitches will have been foreseen and can be avoided.

Reviewer 3:
Current and upcoming project tasks make sense.

Reviewer 4:
As stated earlier, the project is early and it is hard to ascertain the future steps due to the completion of the current steps. Once the models are complete, simulation should provide a solid framework and estimate of the potential savings utilizing intelligent holistic battery management within the boundaries of the test vehicles and locations. Details on the type of environment would be helpful (cities, suburbs, rural delivery routes in Texas and Minnesota, or a combination?).

Reviewer 5:
The presentation indicates that attempts will be made to modify routes for greater efficiency. However, modifying routes is a much more complex question than just trying to optimize energy efficiency and charging points. Delivery deadlines, driver hours of service, vehicle utilization for the next shift, and many other factors are needed to determine optimal routes.

Reviewer 6:
The proposed future research follows a logical progression. The reviewer's concerns were that work for the final year has not been detailed which will include testing and validation. Since performance validation is listed as a barrier (Slide 2), this should be a major emphasis for the team.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
It supports DOE VTO objectives of more energy efficient freight movement and EV technology adoption.

Reviewer 2:
This project will address a major barrier to electric truck operation: inefficiencies that raise costs. In addition, better understanding of how the system works should do much to reduce range anxiety.

Reviewer 3:
Intelligent routing will play an increasing role in petroleum reduction and transportation efficiency.

Reviewer 4:
Energy efficiency, regardless of whether it comes from diesel pump or a charger, is in line with DOE objectives. This project addresses efficiency and can lower the cost of the truck itself through smaller batteries which will also help with adoption. The approach is likely to be commercially feasible because the gains are through algorithms and software development, which can be implemented cost effectively.

Reviewer 5:
This project is quite new and further refinement of the project objectives is necessary to assure support of DOE objectives. The reviewer thought the project has very good potential to provide learning that will further DOE objectives by having a practical demonstration of HD EV implementation in a real-world environment.

Reviewer 6:
The project plan is to research, develop, and demonstrate life cycle cost-effective Class 8 BEVs equipped with an intelligent EMS capable of commercial operations of greater than or equal to 50 miles per day as well as increased efficiency and productivity when compared to baseline 2019 Mack and 2015-2020 Volvo HD battery EV fleet performance.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
There are sufficient resources to complete the project.

Reviewer 2:
Resources appear adequate as the project is on track.

Reviewer 3:
The project appears appropriately funded for the work outlined.

Reviewer 4:
This is always hard to evaluate without much more detail, but funding levels seem reasonable.

Reviewer 5:
The project team has not identified a deficiency though the current COVID situation will strain all resources.

Reviewer 6:
Given the very early state of this project, this is hard to evaluate at this time.

Presentation Number: elt261
Presentation Title: High-Efficiency Powertrain for Heavy-Duty Trucks using Silicon Carbide Inverter
Principal Investigator: Ben Maruqart (Ricardo)

Presenter

Elton Rohrer, Ricardo

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

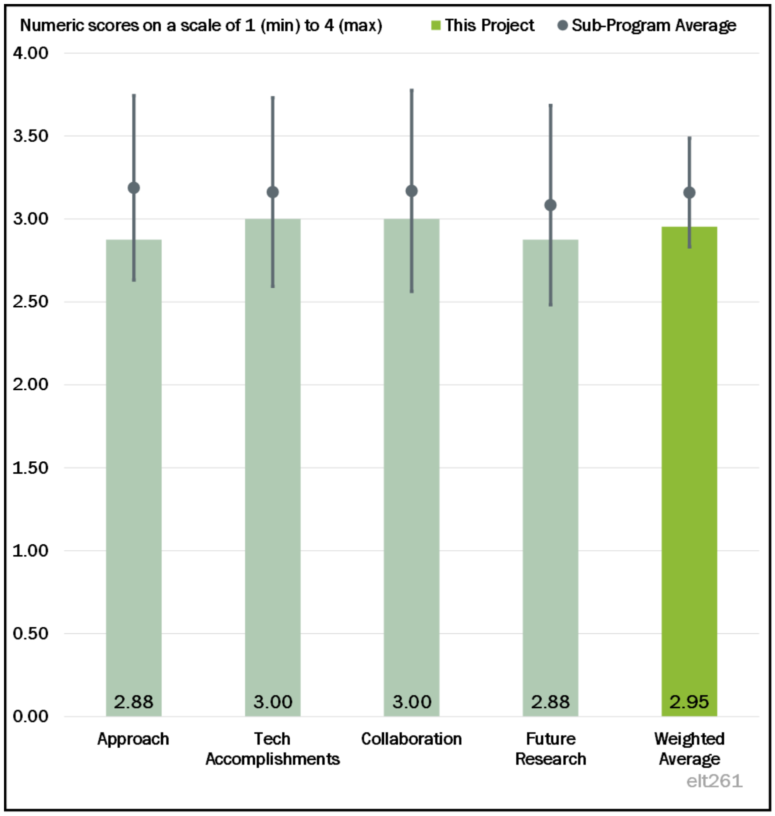

Figure 4-61 - Presentation Number: elt261 Presentation Title: High-Efficiency Powertrain for Heavy-Duty Trucks using Silicon Carbide Inverter Principal Investigator: Ben Maruqart (Ricardo)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project is well designed and feasible to design and develop a class-leading, high-power density, highly efficient 250 kW continuous SiC inverter. Inverter development and drive system component development, subsystem development and system testing, system integration development, and vehicle build vehicle integration and demonstration of two Class 8 trucks are part of the approach.

Reviewer 2:

Prototype design and testing of the 250 kW SiC inverter with efficiency greater than 92.5% in year 1 followed by a greater than 98.5% efficiency SiC inverter in year 2 will lead to quite appropriate hardware for in-vehicle testing in year 3; this is a good approach. This approach allows for overcoming the learning curve, technology risk mitigation, supply chain, and capability build-up followed by prototype hardware testing of a 250 kW SiC inverter in the powertrain for HD trucks.

Reviewer 3:

Technical barriers are mentioned in the presentation, but it seems that little time is devoted to them or how they will be solved. For example, the goal from A samples to B samples is to increase efficiency from 92% to 98.5%. However, the presentation does not mention how this increase will be accomplished. The battery system operating voltage is mentioned as a big barrier, but not why this presents issues or how they will be solved. Integration with the powertrain and testing on vehicles is mentioned as a task, but not how the numerous challenges this presents will be covered.

Reviewer 4:
The reviewer's impression was that the overall project is lacking a systemic approach. The stated objective is to develop and demonstrate a Class 8 BEV but the focus is inverter development. Other than packaging, there is no discussion on integrating and optimizing the system to take advantage of the SiC technology which might include trade-offs in battery size and the traction motor for performance and reliability nor is there a target efficiency for the whole system. Prior work on LD EV applications points to systemic benefits when implementing SiC inverters. The work related to the rest of the vehicle appears to only serve as a demonstration of the inverter which then makes the diesel baseline inappropriate (as opposed to a baseline utilizing Si inverters).

The stated efficiency and power density goals are aggressive though whether the efficiency is peak or average over a duty cycle is not specified.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Proof of concept inverter design has started, and several different simulation scenarios have been completed.

Reviewer 2:
It appears from the presentation material that progress has been made to execute the A sample inverter design and software. Will there be any A sample testing at the vehicle level to start to iron out some of the integration challenges with the first samples before the B sample parts are available? This step is not mentioned in the presentation that the reviewer saw.

Reviewer 3:
The team appears to be making good progress on the stated approach.

Reviewer 4:
The team is making progress; however, there seems no indication that technical progress aligns with the approach. This reviewer doubted that, by end of September 2020, the project team will have a prototype of a 250 kW SiC inverter. Vital parts of inverter are evaluated and selected.

The 250 kW SiC traction inverter system simulation and design tasks seem completed including soft switching scheme simulated in PSIM. Performance of Wolfspeed's SiC power module with part number CAB450M12XM3 for 250 kW power application is understood by project team.

Common-mode and differential-mode (DM) noise generated by inverter as understood by the project team. The project reviewer doubted that the proposed shunt-based current sensing method will lead to any solution that will support targeted high efficiency greater than 98.5 in the SiC Inverter B-sample. This will be quite problematic when battery voltage is 656 V nominal contrary to current sensor simulated at 1000 V DC bus for 250 kW SiC inverter. There is no novelty in the proposed current sensing circuit.

It seems like the team is developing a vehicle, it has electric drive systems and eAxle in collaboration with project partners. It is hard to assess progress from the project report. Looks like the PI is proposing more than he could finish in a year even in collaboration with project partners. This reviewer has high doubts about successful completion of this project.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team consists of Ricardo Inc. as the prime and leading the SiC inverter development, North Carolina State University providing simulation and design expertise support, and TransPower Inc., a wholly

owned subsidiary of Meritor Inc., as a leader in developing and supplying integrated drive systems and full electric truck solutions. This team is collaborating and achieving results.

Reviewer 2:
North Carolina State University's Freedom Systems Center and Trans Power/Meritor are collaborating with the lead organization, Ricardo. All partners have their role identified. It is extremely important that the 250 kW SiC inverter is fabricated and tested in the vehicle platform developed by Meritor.

Reviewer 3:
The presentation articulates activities ongoing with North Carolina State University, but little with Meritot/TransPower so far.

Reviewer 4:
The project team focusing on the SiC inverter appears to be collaborating well as evidenced by their good progress and accomplishments. However, the fact that the chosen battery voltage is a challenge and the lack of details on aspects of the vehicle not related to the inverter are concerns. The slide listing Technical Accomplishments and Progress on the Meritor eAxle (Slide 16) are nearly word for word from the Meritor website, which may indicate that the team working on the remaining powertrain is not entirely engaged.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Future project activities will be focused on the development of the 250 kW SiC inverter to achieve 98.5% efficiency and the system level integration and testing to allow the demonstration of two Class 8 trucks operating for 250 miles daily.

Reviewer 2:
In the proposed future research, relevant topics are stated out in the project report.

Reviewer 3:
The plans for integrating the designs with the e-axle on chassis need to be fleshed out in more detail.

Reviewer 4:
The steps related to the inverter are well documented though there is not much detail on vehicle integration. The challenges listed on Slide 19 (Research Challenges and Barriers) primarily relate to vehicle integration and test issues which are not addressed in the future research.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project will develop highly efficient electric powertrain to allow the acceleration of U.S. truck fleet electrification, which is closely tied with DOE VTO objectives.

Reviewer 2:
Yes, it meets the objectives of improving the efficiency of driving EV powertrains in a much more efficient manner as well as doing so in a much smaller package.

Reviewer 3:
The project does support the overall DOE objectives; however, the 250-mile range is a very limited sampling of Class 8 trucks on the road today. The goal should be much higher: a typical Class 8 truck can run 600 miles on a single load of diesel, a typical route would be 55 miles an hour for 4 hours, stop and then 55 miles an hour

for 4 more hours. So, each leg of the driver's day would be 220 miles, for 440 miles per normal work day. This project should set higher mileage goals on a single charge.

Reviewer 4:
The project is advancing development of the SiC inverter with very aggressive efficiency and power density goals which should contribute to large scale commercial adoption of BEV technology. Missing is discussion on a cost target or commercialization potential and there is limited effort in integrating or optimizing the overall BEV architecture to take advantage of the inverter technology. There is limited innovation apparent relating to the work to integrate the whole vehicle.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Project has sufficient resources to complete the project.

Reviewer 2:
This early in the project, it is hard to tell if resources are sufficient. They appear to be so at this time.

Reviewer 3:
The team does not state that additional resources are needed. The non-integrated approach the team is pursuing may be related to resources, but this has not been stated.

Reviewer 4:
The project has all necessary resources except slow progress made to date. It seems like the project team has promised more than they could deliver.

Presentation Number: elt262
Presentation Title: Long-Range, Heavy-Duty Battery-Electric Vehicle with Megawatt Wireless Charging
Principal Investigator: Brian Lindgren (Kenworth)

Presenter

Brian Lindgren, Kenworth

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

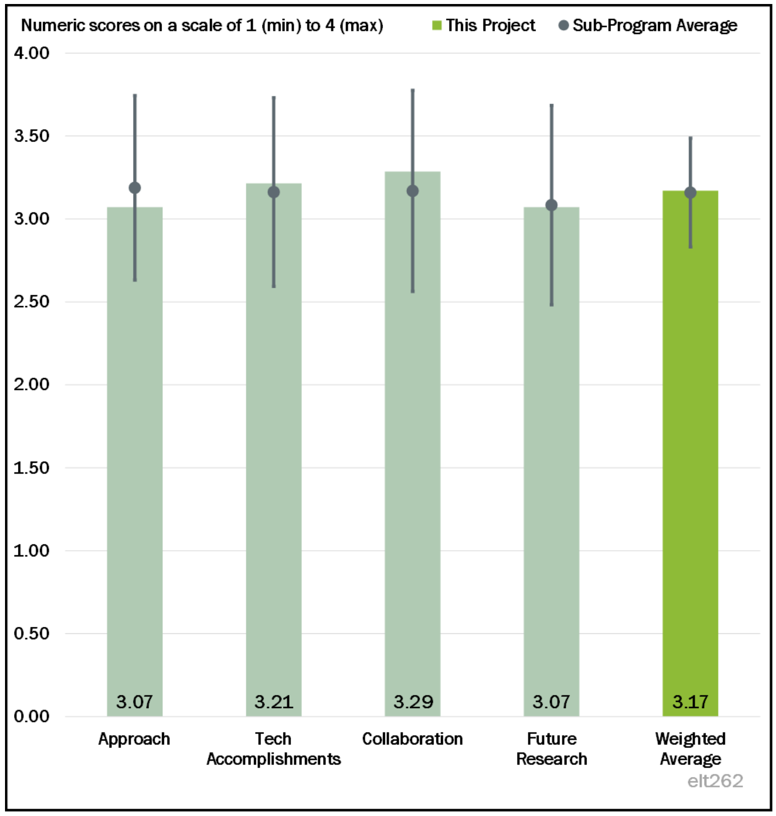

Figure 4-62 - Presentation Number: elt262 Presentation Title: Long-Range, Heavy-Duty Battery-Electric Vehicle with Megawatt Wireless Charging Principal Investigator: Brian Lindgren (Kenworth)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project is in the early stages so it is difficult at this point to ascertain the success of the approach. However, the appropriate mix of collaborators appears present for the project.

Reviewer 2:

Will the project incorporate what is learned from SuperTruck to improve vehicle energy consumption? That was not stated in the approach but would be a big enabler to making this work. It is also not clear why a wireless charging approach would be preferred at this level of power transfer and vehicle specialization.

Reviewer 3:

The project team has taken a customer focused approach with a detailed route analysis as a starting point for the technical specifications. The milestones and timeline are logical and well planned. The reviewer's only concerns are around product cost and customer ROI. The cost of the battery and the incremental wireless infrastructure looks very cost prohibitive.

Reviewer 4:

This project clearly includes all of the pieces needed to address wireless charging of electric trucks and then demonstrating. The reviewer wished the poster contained information on what the team was doing to make the charging happen fast.

Reviewer 5:
The high-level approach seems reasonable but not enough details have been provided. Also, it is not clear why wireless charging is chosen.

Reviewer 6:
It is early on in the project—and understanding the issues with other projects—it is good to see the timeline preparing for subsystem testing in a variety of areas. Still, the approach seems to lack robustness as most milestones are sequential. It may be wise to plan for some parallel task options for the sake of time compression.

Reviewer 7:
The reviewer thought most barriers were at least articulated verbally, but not all were mentioned in the presentation. For example, a 660-kWh battery pack was selected with a “worst case” power consumption on the trip of 450 kWh. However, the 30-minute fast charge could only deliver a maximum of 500 kWh using a 1,000-kW charger. That assumes the full power can be delivered for the full 30 minutes and battery deterioration is not a factor. It seems like that factor of safety may be too small, but testing results will provide direction. The reviewer appreciated that the data gathering process to set the battery pack size was very representative of real-world conditions.

In addition, the EMI aspects of wireless charging at that power level may also be a very large technical barrier. The reviewer thought the project is well designed and feasible as it gets at many aspects of putting this kind of technology into practical service. The reviewer looked forward to reports as it progresses.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The technical work to date is a great start. Real-world data will prevent underestimating the propulsion requirements.

Reviewer 2:
The team has run the route with a range extended electric truck to establish power requirements for all of the major systems and subsystems and determined key parameters including battery sizing which defines the charging requirements. The fact that this was established early using an EV should give the team confidence to continue down its path.

Reviewer 3:
The layout for the tractor hardware is complete. The components and weight limitations can be met allowing for future project implementation.

Reviewer 4:
Considerable thought has obviously gone into design of the charger; the reviewer would like to have seen more detail and maybe schematics of how the on-board charger was going to be laid out.

Reviewer 5:
It is early on in the project, and though the route has been identified and evaluated, vehicle performance information will have a great impact on component selection and evaluation. There was not much in the presentation about vehicle parameters.

There is good work with the magnetics simulation—validating when the vehicle is completed will be late if the model proves to be inaccurate for the new higher power levels.

Reviewer 6:
Progress to date, given the very recent start of the project appears, to be very good. Many partners have been identified and seem on board with the various aspects of the project.

Reviewer 7:
The project is at an early stage and not enough information has been provided.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
All the stakeholders in this type of technical project are represented.

Reviewer 2:
There is reasonable level of collaboration.

Reviewer 3:
An appropriate project team is apparent for this project. A tractor OEM, wireless charging, academic, and public sector team members are coordinated within this project for the demonstration. It is an appropriate blend of partners to complete a demonstration.

Reviewer 4:
The team seems to cover all the bases.

Reviewer 5:
Good representation of team members from needed industries. Because some of these team members are on multiple projects, it will be interesting to see what they learn from other projects and how they will communicate to assist the progression of the technology.

Reviewer 6:
The project is in the very early stages, but the fact that the route was established and tested demonstrates good collaboration among the partners.

Reviewer 7:
The partner selection covers all aspects and appears to be a big plus.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The next steps are appropriate.

Reviewer 2:
There are a lot of good questions to be answered in this project, particularly, the grid impacts and occupant safety of such high-power wireless charging demonstrations. Additionally, determining the battery thermal requirements for high powered charging and use will prove insightful during the demonstration.

Reviewer 3:
The milestone chart outlines key decision points and seems to represent reasonable timing. The reviewer was sure that some barriers will come up over time that may dictate alternate development.

Reviewer 4:
The slide deck was a bit brief in this area, but it is very good to see the references to testing for thermal, high-frequency interference (an industry concern at large air gaps and power levels) as well as leakage field recognition. These are all valuable areas of interest, but no real-world use also means understanding environmental aspects of the operational domain as well as the impacts charging at high rates on a large ESS pack at possible high ambient temperatures will have on pack degradation. It is perhaps wise of the project to focus on power transfer and not have too broad a scope.

Reviewer 5:
Again, information presented is very sketchy. Next year, please specify what information is being collected about power levels, rates, temperature, etc.

Reviewer 6:
The proposed future research addresses critical issues. Not addressed is a question on the efficiency of wireless charging versus a physical plug or where wireless charging is appropriate, given the costs of the hardware and in charging efficiency.

Reviewer 7:
It is difficult to judge until more progress is made and more information provided.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
EVs in this size are a final frontier and advance the DOE VTO goals of greater EV adoption.

Reviewer 2:
Projects which expand fully electric operation into the MD-HD realm deserve to be investigated for commercial readiness and parameter development.

Reviewer 3:
Fast charging and extended range of large trucks are relevant.

Reviewer 4:
Wireless fast charging would certainly contribute significantly to ease of operation and versatility of electric truck operation.

Reviewer 5:
Development and demonstration of electrified power and charging systems for freight will provide key pieces of information relative to grid needs. Additionally, results from such a project can validate or invalidate the current state-of-the-art electrification charging and powertrain technologies relative to heavy truck freight transportation.

Reviewer 6:
This project is a very practical demonstration of implementing battery technology for HD applications and definitely supports DOE objectives.

Reviewer 7:
The project is addressing the charging infrastructure for BEVs, which is one of the barriers to BEV adoption. One concern is that commercial feasibility is not addressed, nor is there involvement or mention of any standards bodies and how a proprietary solution may limit wider adoption.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources appear adequate at this stage of the project.

Reviewer 2:
Resources are sufficient.

Reviewer 3:
The project is early; however, the funds appear sufficient for the project.

Reviewer 4:
It is early on in the project, but based on other projects, the funds should be sufficient to have substantial results to report out to the EV MD-HD community.

Reviewer 5:
At this early point in the project, resources appear to be sufficient and partner involvement seems excellent.

Reviewer 6:
Given the good progress to date and a good mix of partners, the team appears to have sufficient resources.

Reviewer 7:
Again, it is hard to say much here with no cost numbers provided.

Presentation Number: elt263
Presentation Title: Cybersecurity: Securing Vehicle Charging Infrastructure - Consequence Analysis and Threat Assessment
Principal Investigator: Rick Pratt (Pacific Northwest National Laboratory)

Presenter

Rick Pratt, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

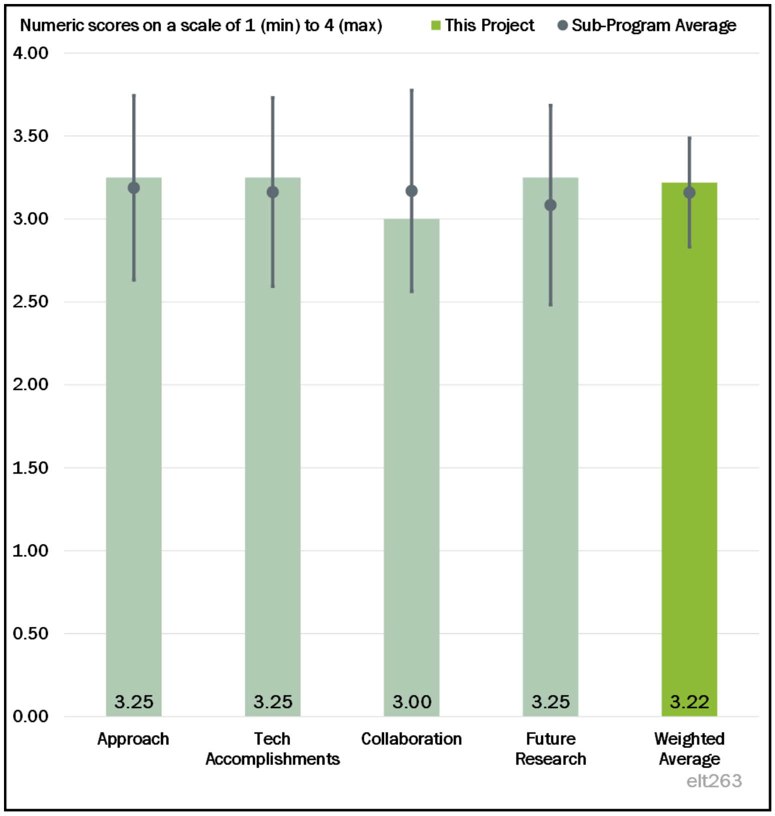

Figure 4-63 - Presentation Number: elt263 Presentation Title: Cybersecurity: Securing Vehicle Charging Infrastructure - Consequence Analysis and Threat Assessment Principal Investigator: Rick Pratt (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The STRIDE methodology being applied is a proven cybersecurity approach. The project approach is selectively addressing several technical barriers yet appears to have appropriately focused the scope of the project in order to attain practical and feasible progress.

Reviewer 2:

Previous studies have not focused specifically on quantifying the potential cyber effects of compromised XFC on the distribution grid, so this is somewhat novel, and beneficial to the mission of VTO and the national security interest. The STRIDE model produced is comprehensive and insightful, providing a valuable perspective on the critical data/power flows, actors, and components relevant to XFC charging (this STRIDE model has been presented by SNL, and framed as an SNL-led project: it is not clear if this is the same project (novel), or borrowed from a separate VTO-funded project). The modeling and simulation efforts are a valuable exercise, but could benefit from going “bigger,” e.g., SNL showed that a 10,000 MW static load has minimal effect on WECC—therefore there may be greater value in modeling significantly more than 500 MW. Additionally, the relevance, accuracy, and transition value of the project would be substantially increased if real assessments were performed against XFC ecosystems and distribution components (recognizing the challenges in getting access to systems that this testing can safely be performed on).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The progress to date has created meaningful results with respect to each of the barriers being addressed.

Reviewer 2:
Project appears to be on schedule. Stated goals of developing threat models and dynamic simulations have been met, and improvements on both are underway. Likely knowledge transfer goals are being met through multiple publications and presentations, increasing awareness of the risks posed by XFC. Milestones stated in the slide deck appear to have been met. However, threat and vulnerability assessments, as stated, appear to be a paper exercise (e.g., an analysis)—better technical achievement could be gained from practical assessments. These are suggested to have occurred by other project partners, but it is not clear if these are part of the PNNL project based on presentation contents and limited DOE funding.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project appears to have good coordination with the other National Laboratories (ANL and SNL) and very good communication of the work with domain relevant R&D forums such as the GITT and an EPRI working group.

Reviewer 2:
Collaboration is not highlighted in the presentation. Low involvement and retention of industry partners is apparent (e.g., early stage involvement of new industry partner, Florida Power & Light—just now executing a non-disclosure agreement.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Threat models and consequence events identified have good potential transition value for OEMs/product security organizations, and for DOE in follow-on funded research focused on validating and measuring threats through practical assessments. Modeling and simulation of adverse effects on WEC have likely transition value for commercial utilities and regulators, as well as other DOE National Laboratories and DOE-funded research.

Reviewer 2:
The proposed future work is logical to the realization of the proposed advancements, especially in the inclusion of validation and verification work for the threat analysis and mitigation strategies. However, this reviewer was concerned that the threat analysis may be exposing electric grid vulnerabilities to the public with the potential to educate bad actors and to the detriment of grid security. Please consider limiting dissemination of the results until they can be evaluated by DOE and the U.S. Department of Homeland Security regarding possible national/grid security implications.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is directly relevant to DOE's Cybersecurity Multi-Year Program Plan objective to "Complete end-to-end threat informed and consequence driven vulnerability assessment of EV/charging/grid interactions. (FY 2020)".

Reviewer 2:
Alignment of project goals with DOE objectives is apparent. DOE stated in 2018 (?) the goal of understanding threats that XFC pose to critical infrastructure and national security—project goals and vision directly contribute thereto. However, to maximize transition value, practical assessments should be included, best practices and design recommendations should be produced, and models should be released and licensed as open-source and be reusable by industry.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project is generating productive results with the allocated resources.

Reviewer 2:
According to the reviewer, $1 million and a 3-year project between three National Laboratories plus industry seems insufficient to produce quality results; however, the apparent progress (gained exclusively from the presentation contents) exceeds expectations for the level of funding provided by DOE. Perhaps the competitive lab model struggles here, where multiple laboratories now share specialties (e.g., in EV/EVSE cybersecurity) and must split very limited funds for collaborative research.

Acronyms and Abbreviations

°C	Degrees Celsius
3-D	Three-dimensional
AC	alternating current
Al	Aluminum
ANL	Argonne National Laboratory
AMR	Annual Merit Review
ATF	Automatic transmission fluid
B	Magnetic flux density
BAU	Business as usual
BEV	battery electric vehicle
BP	Budget period
CADS	Cyber anomaly detection system
CaF_2	Calcium fluoride
CFD	Computational fluid dynamics
cm	Centimeter
CMOS	Complementary-symmetry metal
CNG	Compressed natural gas
Cu	Copper
DBC	Direct bonded copper
DC	Direct current
DCFC	DC fast charging
DER	Distributed energy resources
DoD	Department of Defense
DOE	U.S. Department of Energy
DOT	Department of Transportation
DSS	Distribution System Simulator
DTNA	Daimler Trucks North America LLC
DWPT	Dynamic Wireless Power Transfer

Dy	Dysprosium
EETT	Electrical and Electronics Technical Team
ELT	Electrification Technologies
EMG	E-Mobility Group
EMI	Electromagnetic interference
EMS	Energy management system
EPRI	Electric Power Research Institute
ESS	Energy storage system
EV	Electric vehicle
EVSE	Electric vehicle supply equipment
FCML	Flying Capacitor Multilevel
Fe_4N	Iron nitride
FEA	Finite element analysis
FeCo	Iron-cobalt
FY	Fiscal year
GaN	Gallium nitride
GAO	Genetic algorithm optimization
Georgia Tech	Georgia Institute of Technology
GITT	Grid integration technical team
GM	General Motors
H	Magnetic field strength
HALT	Highly accelerated lifetime test
HCEs	High consequence events
HD	Heavy-duty
HELICS	Hierarchical Engine for Large-scale Infrastructure Co-Simulation
HEMT	High-electron-mobility transistor
HIL	Hardware in the loop
HRE	Heavy rare earth

Hz	Hertz
ICE	Internal combustion engine
IEEE	Institute of Electrical and Electronics Engineers
IIC	Indiana Integrated Circuits
IMS	Insulated metal substrate
INL	Idaho National Laboratory
IPM	Interior permanent magnet
JBS	Junction barrier Schottky
JRC	Joint Research Center
kW	Kilowatt
kWh	Kilowatt hours
L	Liter
LD	Light-duty
MD	Medium-duty
Mg_2SiO_4	Forsterite
mm	Millimeter
MnBi	Manganese bismuth
MOSFET	Metal oxide semiconductor field effect transistor
MPGe	Miles per gallon equivalent
MTC	Metropolitan Transportation Commission
MV	Medium Voltage
MW+	Megawatt plus
NA	North America
NdFeB	Neodymium iron boron
NIC	Network interface card
NMFTA	National Motor Freight Traffic Association, Inc.
NREL	National Renewable Energy Laboratory
NREL80	80-mile work day duty cycle developed by NREL

ODBC	Organic film based direct bonded copper
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
OSU	Ohio State University
PEVs	Plug-in electric vehicles
PG&E	Pacific Gas & Electric
PI	Principal Investigator
PKI	Public key infrastructure
PM	Particulate matter
PM	Permanent magnet
PNNL	Pacific Northwest National Laboratory
PU	Per unit
PV	Photovoltaic
PWM	Pulse width modulation
R&D	Research and development
RE	Rare earth
RMS	Root mean square
ROI	Return on investment
SAE	Society of Automotive Engineers
SBD	Schottky barrier diode
SCAQMD	South Coast Air Quality Management District
SDOs	Standards developing organizations
Si	Silicon
SiC	Silicon carbide
SMC	Soft magnetic composites
SNL	Sandia National Laboratories
SPIN	Smart Power Integrated Node
SPM	Surface permanent magnet

STRIDE	Spoofing, tampering, repudiation, information disclosure, denial of service, elevation of privilege
SUNY Poly	State University of New York Polytechnic
TCO	Total cost of ownership
THD	Total harmonic distortion
TLP	Transient liquid phase
TPG	Thermal pyrolytic graphite
U.S.	United States
U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability
UPS	United Parcel Service
V	Volt
V2G	Vehicle-to-Grid
VDC	Volts of direct current
Virginia Tech	Virginia Polytechnic Institute
VTO	Vehicle Technologies Office
WBG	Wide bandgap
WECC	Western Interconnection model
WXFC	Wireless extreme fast charging
XFC	Extreme fast charging
ZECT II	Zero-Emission Cargo Transport II

5. Fuel and Lubricant Technologies

The Vehicle Technologies Office (VTO) has a comprehensive portfolio of early-stage research to enable industry to accelerate the development and widespread use of a variety of promising sustainable transportation technologies. The research pathways focus on fuel diversification, vehicle efficiency, energy storage, and mobility energy productivity that can improve the overall energy efficiency and efficacy of the transportation or mobility system. VTO leverages the unique capabilities and world-class expertise of the National Laboratory system to develop innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures; and energy efficient mobility systems. VTO is uniquely positioned to address early-stage challenges due to strategic public-private research partnerships with industry (e.g., U.S. DRIVE, 21st Century Truck Partnership) that leverage relevant expertise. These partnerships prevent duplication of effort, focus DOE research on critical R&D barriers, and accelerate progress. VTO focuses on research that industry does not have the technical capability to undertake on its own, usually due to a high degree of scientific or technical uncertainty, or that is too far from market realization to merit industry resources.

The Fuel and Lubricant Technologies (FT) subprogram supports early-stage R&D to improve our understanding and ability to manipulate combustion processes, fuel properties, and catalyst formulations, generating the knowledge and insight necessary for industry to develop the next generation of engines and fuels for light- and heavy-duty vehicles. As a result, co-optimization of higher-efficiency engines and high performance fuels has the potential to improve light-duty fuel economy by 35% (25% from advanced engine research and 10% from co-optimization with fuels) by 2030 compared to 2015 gasoline vehicles. The subprogram supports cutting-edge research at the National Laboratories, in close collaboration with academia and industry, to strengthen the knowledge base of high-efficiency, advanced combustion engines, fuels, and emission control catalysts. The FT subprogram will apply the unique facilities and capabilities at the National Laboratories to create knowledge, new concepts, and research tools that industry can use to develop advanced combustion engines and co-optimize with fuels that will provide further efficiency improvements and emission reductions.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0)*. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 5-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ft037	Co-Optimization of Fuels and Engines (Co-Optima)	Robert Wagner (ORNL/NREL)	5-4	3.30	3.30	3.70	3.30	**3.35**
ft067	Multi-Mode/Multi-Mode Compression Ignition : Fuel-Property Characterization and Prediction	Tim Bays (NREL/PNNL)	5-10	3.19	3.44	3.50	3.31	**3.37**
ft069	Multi-Mode: Fuel-Property Impacts and Limitations on Combustion–Spark Ignition Focus	Derek Splitter (ORNL)	5-17	3.43	3.29	3.36	3.43	**3.35**
ft070	Multi-Mode: From In-Cylinder Combustion Diagnostics to Drive-Cycle Fuel Economy	Magnus Sjoberg (SNL)	5-23	3.00	3.10	3.40	3.00	**3.10**
ft071	Multi-Mode Operation in Gasoline Direct-Injection Engines: Fuel-Property Effects and Approaches to Expand the Advanced Compression-Ignition Range	Toby Rockstroh (ORNL)	5-28	3.00	3.33	3.67	3.25	**3.28**
ft072	Multi-Mode: Desired Fuel Properties for Advanced Compression-Ignition and Spark-Ignition Engine Performance	Chris Kolodziej (ANL)	5-33	3.40	3.50	3.20	3.20	**3.40**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ft073	Co-Optima Emissions and Emissions Control for Spark Ignition and Advanced Compression Ignition Multi-Mode Combustion	Sreshtha Sinha-Majumdar (ORNL)	5-38	3.50	3.43	3.36	3.21	**3.41**
ft074	Multi-Mode: Gasoline Direct-Injection Sprays	Lyle Pickett (SNL)	5-44	3.60	3.90	3.60	3.50	**3.74**
ft075	Multi-Mode: Fuel Kinetics	Bill Pitz (ANL/LLNL)	5-48	3.71	3.50	3.86	3.50	**3.60**
ft076	Model-Based Fuel and Engine Optimization	Juliane Mueller (LBNL)	5-53	3.10	3.50	3.30	3.20	**3.34**
ft077	Heavy-Duty Mixed-Controlled Compression Ignition: Fuel Effects and Ducted Fuel Injection	Charles Mueller (SNL)	5-57	3.63	3.88	3.38	3.75	**3.73**
ft078	Heavy-Duty Mixed-Controlled Compression Ignition: Impacts of Fuel Properties on Combustion, Injection Characteristics, and Emissions Controls	Martin Wissink (ANL/ORNL)	5-60	3.25	3.25	3.42	3.33	**3.28**
ft087	Multimode, Co-Optimized, Light-Duty Vehicle Engine	Phil Zoldak (Hyundai-Kia North America)	5-65	3.30	3.40	3.20	2.90	**3.29**
ft088	Fuel Property Experimental Kinetics	Gina Fioroni (NREL)	5-69	3.70	3.70	3.60	3.30	**3.64**
ft089	Heavy-Duty Advanced Compression Ignition	John Dec (SNL)	5-73	3.30	3.40	3.40	3.50	**3.39**
Overall Average				**3.36**	**3.45**	**3.47**	**3.31**	**3.41**

Presentation Number: ft037
Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)
Principal Investigator: Robert Wagner (Oak Ridge National Laboratory)

Presenter

Robert Wagner, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

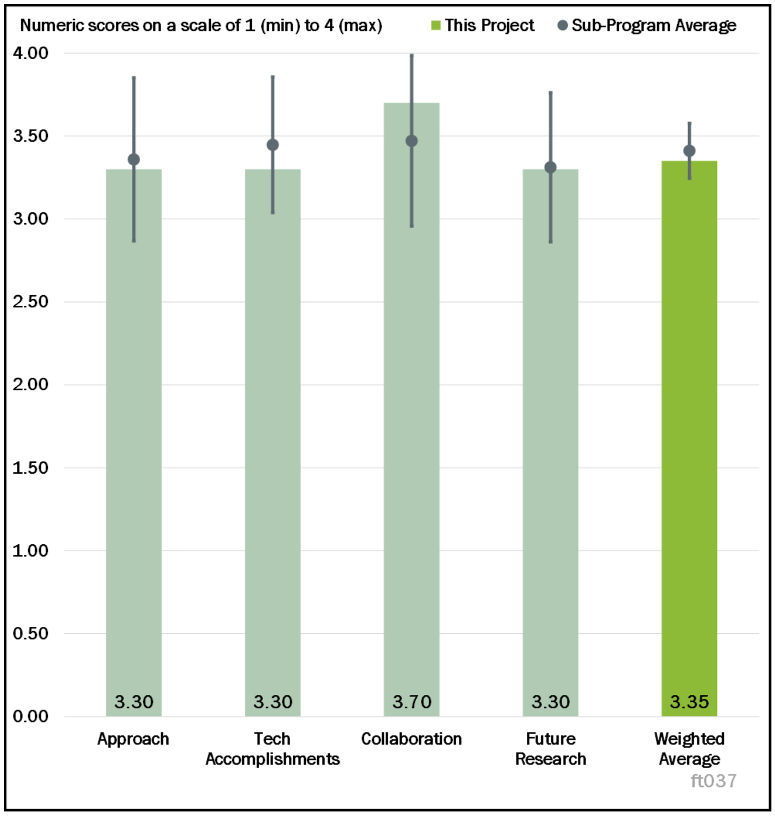

Figure 5-1 - Presentation Number: ft037 Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima) Principal Investigator: Robert Wagner (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The encompassing approach of Co-Optimization of Fuels and Engines (Co-Optima) is very good. It is a multi-laboratory effort, working in experimental and simulation space, both for light-duty (LD) and heavy-duty (HD) engines. The project is looking at costs of fuels, understanding of combustion, and fundamental understanding of how fuel properties influence ignition and combustion. All of these aspects are very important. One item that was conspicuous by its absence is the potential for this project to leverage critical fuels technologies and economics to enable United States (U.S.) companies to meet upcoming greenhouse gas (GHG) regulations while maintaining and improving efficiency and meeting ever-tightening toxic air emissions standards. The ability to be a major lever in helping original equipment manufacturers (OEMs) to achieve GHG regulatory compliance needs to be a more important focus to this project.

Reviewer 2:

The approach is very strong and is continuing to get better. The collaboration continues to get stronger and with it the identification of the research on critical barriers is becoming more sharply focused.

Reviewer 3:

The team has done a great job setting up the program over the past years.

Reviewer 4:

Historically, the overall Co-Optima program approach has been solid, drawing in the strengths of laboratories across the U.S. Department of Energy (DOE) complex to align on topics surrounding fuels and engine research. The highest value results from the program focus on fundamental fuel property understanding, with engine-fuel interactions a close second. Within the scope of the program, however, there are some projects that look to be rolled into the effort even though they are not centrally aligned with the Co-Optima mission. In addition, there are activities that appear focused on increasing the scope of a specific laboratory's capabilities, in some cases duplicating capabilities that already exist in other labs. These are of lower value.

This reviewer would have liked to see more high-level alignment with the SuperTruck 2 (ST2) program, because this DOE-funded program represents the cutting edge of high-efficiency, HD line-haul truck development. As Co-Optima morphs to a stronger focus on the HD space, ensuring the research goals and efforts are aligned with the needs identified by the SuperTruck 2 program is important. As an example, many of the SuperTruck projects, both SuperTruck 1 (ST1) and SuperTruck 2, included some level of work on an advanced compression ignition (ACI) concept. ACI technology packages were down-selected out of all projects as they moved forward, reflecting that a mixing-controlled combustion solution was the most promising for delivering the efficiency targets. The Co-Optima shift in focus seems to run counter to this knowledge, raising the question on what is driving the shift in focus. Is this an industry pull, like it was for LD mixed-mode combustion, or a DOE laboratory push? As efforts move forward, ensuring a close connection to the SuperTruck 2 projects is critical to ensure Co-Optima is both utilizing knowledge gained in their projects and responding to the barriers and opportunities they identify.

This reviewer would have liked to see more focused and concrete deliverables for the computational fluid dynamics (CFD) and simulation activities and additional clarity of what is being delivered on the simulation side. How to effectively incorporate fuel properties into CFD simulations is still an open question and area for development, but it is critical to have robust governance on the project outputs. The newly formed Partnership for Advanced Combustion Engines (PACE) program has a strong focus on delivering useful open-source sub-model outputs from the simulation work, which would be a good model for Co-Optima to adopt to ensure the simulation projects are delivering useful results.

The LD focus on mixed-mode combustion is still a strong topic and it would be good to bring this effort to a strong finish. Decisions on when to move on from this topic should be dictated by the research progress and state of conclusions rather than artificial external timelines. This reviewer was encouraged by the decision to extend the mixed-mode effort. Taking the time necessary to have a definitive result and outcome is far more valuable than quickly pivoting to chase after new topics of the day. In many cases, it beggars belief that the projects that quickly churn out a result and are ready to move on to the next topic are truly delivering high-impact work. The reviewer recommended letting the transition to new areas be driven by the impact of the work, the results to answering key questions, and the resolution of technology barriers and not just the first to "complete" a task.

The reviewer suggested that Co-Optima to consider dialing the focus of the program into more narrowly tailored areas and to give the program the time to deliver high-impact work. The reviewer recommended the program not be too driven to cover all possible fuel-engine research questions and transition to the next flashy topic based on a timeline external to whether work is truly complete and impactful in a given area.

One of the challenges and barriers listed is the mismatch between engine and blendstock development research. This is a very clear issue in the program, and there is a clear need to spend more effort to bring alignment between the blendstock development and the combustion development programs. No paths forward were highlighted, however. The reviewer believes co-optimization cannot occur if the two programs are not in sync.

Reviewer 5:

The approach focuses on finding a new fuel, blending agent to gasoline, or expanding the understanding of existing gasoline fuel properties to enable low-temperature combustion (LTC) or ACI modes. While this work is needed, it is focused largely on increasing engine efficiency. There seems to be far less effort on overcoming the following barriers to LTC/ACI combustion, which must be overcome before commercialization can be considered; not to mention, that if a new fuel blend is needed, commercialization of that new fuel has its own challenges:

- Expanded speed and load range of LTC regime
- Reduced engine-out hydrocarbon (HC) and carbon monoxide (CO) emissions
- Lower combustion noise
- Simpler transient control/combustion mode switching
- Improved cold operation
- Lower boost pressure
- Higher specific power
- Crank angle at 50% mass fraction burned (CA50) control and tolerance to boundary condition perturbations:
    - Ambient temperature
    - Humidity
    - Market fuel variability
- Low-cost lean-oxides of nitrogen (NO_x) aftertreatment system.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The technical accomplishments are excellent.

Reviewer 2:
There has been substantial progress in this project over the last year. Fuel properties, advanced combustion, and more precise and accurate measurement and prediction of fuel properties—all of these are critically important as we head to a more sustainable future for liquid fuel powered vehicles. One aspect that might be worth more pursuit is the ability of these fuel components or blendstocks to be an enabler for a practical LTC engine.

Reviewer 3:
The reviewer observed great progress to date and some of the more exciting projects in fuels since gasoline blended with 10.5%-15% ethanol (E15).

Reviewer 4:
Progress had been good but more work in the right areas, namely, spark-assisted homogeneous charge compression ignition (HCCI) type mixed mode, is needed to help overcome the challenges in mixed-mode combustion for LD application.

Reviewer 5:
The program seems to have lost some focus in the transition from Co-Optima 1.0 to 2.0. The boosted spark ignition (SI) efforts in Phase I had clear engagement and strong partnerships across the DOE laboratories. The ability of the group to come together and develop a merit function for boosted SI engines with a strong technical backing was a good result. The 2.0 effort appears significantly less focused and more prone to uncoordinated efforts with multiple research probing vastly different topics. The concern here is that the final result from Co-Optima 2.0 may have very low impact on the key questions and opportunities it was designed to explore.

There is a clear need to identify the high-level arc of a specific research topic, so that it is possible to understand how the project is measurably progressing along the path to deliver a solution or understanding in a given area. As an example, what is the key challenge or barrier for mixed-mode combustion? How are projects aligned to deliver understanding against that barrier? What are the key steps along that path? This is only one example, but this approach is needed broadly across all of the topics across the effort. Understanding the arc of the program is important to understanding the scale of progress being made.

There is no doubt that the program is delivering high quality work across a broad range of topic areas. The significant volume of technical publications delivered is to be lauded.

The program logs completion of many milestones, and a few highlighted go/no-go decisions, across the different projects that are a part of the overall effort. Moving forward, there should be a focus to ensure milestones are meaningful measures of progress of the effort and less process-based check boxes that are easily achieved. The go/no-go milestones should also be explained in the context of significant program decisions. Identifying key break points in the effort, and developing go/no-go milestones or decision points, is far more instructive than a process check, such as the ducted fuel injection (DFI) go/no-go highlighted this year. This reviewer proposed using the go/no-go as higher-level project management tools.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration and coordination in Co-Optima is outstanding. There is a coherent, integrated work plan, and it appears that each team member does a good job of communicating and ensuring that their work fits into the overall goals. The inter-lab cooperation is impressive because that is very difficult to establish and maintain. The integration between experiment and simulation is also impressive from a global point of view.

Reviewer 2:
Since its inception, Co-Optima has progressed from essentially disparate projects to a closely coordinated program with well-focused projects. The reviewer sent kudos to the leadership.

Reviewer 3:
There is excellent collaboration across many partners.

Reviewer 4:
The Co-Optima team is to be congratulated on achieving excellent collaboration among the various National Laboratories. The program has paved the way and set the example for collaboration in future DOE programs like PACE.

Reviewer 5:
Under the broad heading of Co-Optima, there is coordination across the overall team driven by the program structure. On a more local level, it is less clear that the coordination and collaboration exists across all project teams. There are examples of programs with clear cross-laboratory collaboration and others with very limited connectivity.

With the shift to Co-Optima 2.0, and the new research program areas, the targeting and alignment of teams around central project objectives become increasingly muddied. The work seems more scattered, and it is clear some of the long-standing DOE lab siloes are starting to reappear within certain project scopes. Moving forward, the program needs to focus on pressing for more multi-laboratory initiatives and closer collaborations to deliver on a common goal. Focusing on narrowing the breadth of the projects, with an increase in technical depth on a reduced number of subjects, could help increase the coordination and collaboration across efforts.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Proposed future work in ACI is probably the right pathway from a combustion point of view, while finishing up work on mixing-controlled compression ignition (MCCI) combustion. One thing this reviewer would like to have seen is an overall goal toward reducing the well-to-wheels (WTW) carbon dioxide (CO_2) footprint between combustion system (including engine efficiency) and fuel choice (low carbon/high performance fuels). The combination of efficiency and low carbon fuel will directly impact the WTW compliance for GHG. It would be nice to see this presented more prominently.

Reviewer 2:
It was not clear to this reviewer the extent to which the future work on multi-mode engine combustion will contribute to the current understanding in industry of what is required to overcome the challenges of implementation. Demonstration vehicles have been built and Mazda has announced market introduction.

The barriers identified for medium-duty (MD) and HD vehicles seem reasonable.

It seemed to this reviewer that testing the central fuel and central engine hypotheses is an important task. It also seems that it will be challenging and perhaps involve a significant effort. How is this going to be integrated into your future plans?

Reviewer 3:
The proposed near-term research efforts look reasonable and are solid, next-step progressions of the ongoing work. The reviewer noted that inclusion of a specific principal investigator (PI) name to the planned outcomes in fiscal year (FY) 2021, on Slide 25 highlights again the question of coordination and collaboration across the laboratory space. If individual PIs are responsible for key future deliverables, that makes the project appear less of a cohesive effort and more a collection of independent projects. Are all PIs driving work to these central outcomes?

A focus of later stage effort on reduction of overall transportation CO_2 is a good target, but with a few clear caveats:

- Scale is a critical factor, and analysis will need to be targeted on what fuels can be delivered, and consumed, at a meaningful scale. A narrow range of specialized applications at low volumes is not impactful. A focus on impact to the whole transportation system could be impactful.
- There are a lot of ongoing efforts globally, both commercial and in the research and development (R&D) space, focused on this topic, so the effort will have to be carefully defined to ensure that it builds upon these efforts, not just repeating them from the start.
- How this effort fits within the central concept of Co-Optima, that optimizing fuels and engines in concert will enable high system-level gains, will need to be clear.
- Need to ensure that the current work is complete and has delivered meaningful outcomes.

Reviewer 4:
There is limited room to improve MD and HD engines via fuel properties and engine design. The reviewer recommended taking a wider view and including some future electrification in the mix. This will allow Co-Optima to downsize the engine, where the fuel and engine design could really allow a novel engine to significantly improve efficiency. Running a 9 liter (L) versus 15 L may be possible with some hybridization, for example. This would require running the 9 L engine at a much higher load on typical drive cycles. It also

changes the operating points for mixed-mode combustion regimes and may result in disqualifying certain fuels/regimes due to high NO_x.

Reviewer 5:
It is suggested that the LD portion of Co-Optima 2.0 on mixed-mode combustion be brought to a crisp end and focus shifted to programs like PACE.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This is exactly the type of program that DOE should be funding—improving efficiency and reducing GHG footprint to help American companies better compete and to meet upcoming regulatory constraints at the same time.

Reviewer 2:
This work is very relevant. To reduce the CO_2 footprint of our mobility system to a level necessary for sustainability will require the optimization of the entire fuel, engine, etc., system. This is the focus of Co-Optima.

Reviewer 3:
The Co-Optima program has strong alignment with DOE focus areas on increasing vehicle efficiency and increasing fuel diversity.

Reviewer 4:
Co-Optima supports the DOE goals.

Reviewer 5:
The program all along has sought to reduce petroleum consumption and address GHG emissions.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The scope and resources of this program are appropriate for the targets and goals that it seeks to achieve.

Reviewer 2:
Resources seem sufficient.

Reviewer 3:
The resources are at a healthy level without being excessive.

Reviewer 4:
The assigned resources have been used well.

Reviewer 5:
Overall program funding is reasonable, given the broad scope of the effort. On an individual program basis, there are some broad disparities in funding level that are not fully accounted for or explained. Some project funding levels may be insufficient, while others appear notably excessive.

Presentation Number: ft067
Presentation Title: Multi-Mode/Multi-Mode Compression Ignition: Fuel-Property Characterization and Prediction
Principal Investigator: Tim Bays (Pacific Northwest National Laboratory)

Presenter

Tim Bays, Pacific Northwest National Laboratory; Gina Fioroni, National Renewable Energy Laboratory; Matt McNenly, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of eight reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 88% of reviewers indicated that the resources were sufficient, 13% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

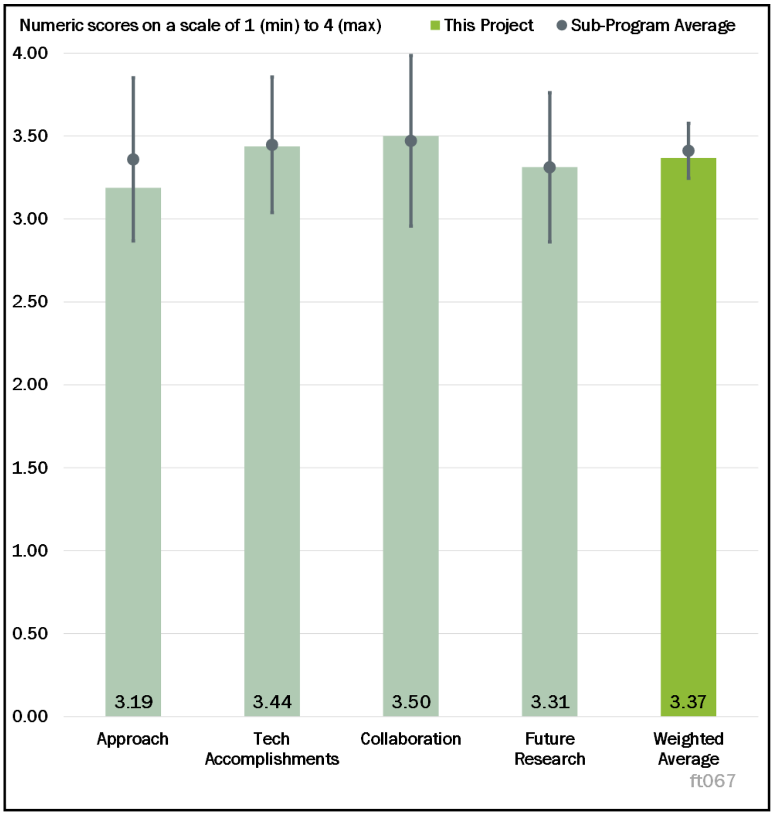

Figure 5-2 - Presentation Number: ft067 Presentation Title: Multi-Mode/Multi-Mode Compression Ignition: Fuel-Property Characterization and Prediction Principal Investigator: Tim Bays (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Pacific Northwest National Laboratory’s (PNNL) (Bays) approach to understanding of the influence of oxygenate clustering on fuel properties affected by distillation is the well-planned and thought-out research expected from a National Laboratory. This research is important in understanding combustion and more importantly LTC. which may be sensitive to certain fuel property effects. Dr. Bay’s approach using nuclear magnetic resonance (NMR) is unique.

National Renewable Energy Laboratory’s (NREL) (Fioroni) research into the impact of azeotropes on heat of vaporization (HOV) and species evolution uses a unique tool and approach to develop HOV information that will be useful for engine designers and researchers in the future.

Reviewer 2:

The project is well focused and planned to deliver underlying knowledge and data on fuel effects in engine combustion and fuel-blending phenomena. Coordination with the Vehicle Technologies Office (VTO) and the Bioenergy Technologies Office (BETO) participants appears good.

Reviewer 3:
This project aims to improve the measurement of critical fuel properties relevant to engine efficiency, including gasoline volatility and evaporation, relationships to azeotropic behavior, and predictive modeling of properties that blend non-linearly. The project also focuses on advancing the underlying science needed to develop biomass-derived fuel and advanced engine technologies. The scope and the tools available to this project team all are well suited to making significant progress on improving our understanding of the objectives above.

Reviewer 4:
This fundamental work will be very powerful if and when it can be more closely associated with modeling for sprays, combustion, and emissions. The team does now have that work planned for 2021, and it will be the critical link for ultimate utilization of the fundamental work.

It is surprising that the Aspen model can correctly predict spikes in instantaneous heat of vaporization (iHOV) behavior for gasoline-alcohol blends during evaporation, and yet we know so little about the causality. Detailed analysis of the modeling architecture could suggest the route to further experimental campaigns for full comprehension of these effects. Spikes in the iHOV like this will have a substantial impact on eventual spray and evaporation modeling.

Reviewer 5:
The point of some of this fundamental work is not really clear to this reviewer. The molecular modeling to predict evaporation behavior is interesting in and of itself, but has no tie to any physical measurements that show there is a significant impact of the variables considered on the spray evaporation and resulting engine behavior. This reviewer had no doubt that there are differences, but the significance factor is key. If this does not help an OEM make its engine better or a fuel company make its fuel better, then the work does not really accomplish much of engineering value (scientific value, yes, but that is a different program). The work to predict research octane number (RON) and motor octane number (MON) is useful, especially in the context of blend studies. As previous reviewers noted, this does not cover everything that we need to understand about the fuel, but it is a good first step.

Reviewer 6:
Investigations into the impacts of molecular clustering on vapor pressure (Task F.1.2.2a) and investigations into the instantaneous heat flux of evaporating mixtures (Task F.1.3.2) are both technically sound and have the potential to shed light on fundamental processes influencing how fuels move from the liquid to the gas phase. However, particularly in the case of the instantaneous heat flux measurements (Task F.1.3.2), a key question is whether the phenomena observed in the benchtop experiment will be relevant to practical engines, in which liquid fuel evaporation timescales are presumably much shorter, reducing the time available for diffusion within the liquid during evaporation.

The neural-network approach (Task G.1.1a) to fuel blending models being developed by Lawrence Livermore National Laboratory (LLNL) is offering high-accuracy predictions of fuel properties and beginning to exceed predictions of existing, well-regarded blending models while offering the ability to utilize more precise descriptions of mixtures.

Reviewer 7:
In general, all sub-projects under FT067 are addressing the objective of the project to characterize and predict fuel properties relevant to engine combustion (MM or otherwise). There is a disconnect between the stated barriers on Slide 2, which emphasize fuel kinetics and LTC, and the sub-projects included in the presentation. None of the sub-projects is directly addressing fuel kinetics or LTC. However, the fuel property characterization and prediction being targeted by the sub-projects—including fuel volatility (vapor pressure), evaporation, and knock resistance (octane)—are critical for improving the modeling capabilities of current engine simulation tools, and the associated teams are encouraged to continue their fundamental research.

Reviewer 8:
The order of operations in this project seems out of order for efficiency. For example, the reviewer suggested starting with the actual measurements of fuel evaporation and only going on to the very complex work with the molecular dynamics simulations. It looked to the reviewer that this is an awful lot of work to undertake when there is not much difference.

Additionally, this presentation often failed the "so-what?" test (made famous by another reviewer, who encapsulated this comment in a question during the presentation)—the reviewer spent quite a lot of time reading and re-reading the yellow bar take-away messages on each slide (for example, Slide 8) to try to figure out what is the real conclusion in terms of the application of the new fundamental knowledge gained in this work.

The reviewer indicated that the overall work done in this project is solid, but that the significance of the work is not well described in the presentation. For example, the reviewer was able to learn from some fuel industry colleagues that this work relates well to the refinery models, but that was never made clear in the presentation. In addition, the reviewer thought there was a missed opportunity to point out (from what could be seen in the slide) that the error analysis showed that the model has better results than an octane engine.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Although many projects have been slowed due to the COVID-19 pandemic this year, important findings have been produced on the effects of oxygenate clusters and better prediction of octane numbers in blends that have non-linear characteristics. The overall record of publications is strong.

Reviewer 2:
The team made significant progress in understanding how oxygenate clusters and networks contribute to vapor pressure, finding the dominating interactions of gasoline-alcohol blend evaporation, and developing a neural network model for the predictions of fuel properties.

Reviewer 3:
The reviewer stated these are great fundamental efforts, for which the community is impatiently clamoring for the eventual utilization of these efforts to enhance the predictive spray and combustion modeling tools.

Reviewer 4:
This project has made very good progress over the past year. Some of the notable accomplishments include:

- Better understanding of the impact of oxygenate clusters on fuel volatility and evaporation
- Improved characterization of the HOV
- Development and refinement of a neural network-based model to identify fuel blends with desirable properties.

The ability of the blending model to accurately estimate fuel RON and MON is quite impressive. The neural network based model seems to be a promising tool for optimizing fuel blends with targeted properties.

The aforementioned accomplishments, along with others, demonstrate progress toward DOE's higher-level goals. However, the absence of well-defined performance indicators makes it difficult to quantify the progress toward DOE's goals. Considering that DOE's guidelines require progress to be evaluated against well-defined performance indicators, the project team should consider making a concerted effort to show such information in the Annual Merit Review (AMR) presentation.

Reviewer 5:
By furthering the understanding of clustering, azeotropes, and HOV, the researchers are enabling a better understanding of non-linear blending effects such as octane and distillation. The researchers are making great technical progress.

Reviewer 6:
The technical results presented here are of high quality, providing fundamental insights into the phase change of fuels and demonstrating the robustness of the approach to fuel-blending models.

Reviewer 7:
The progress on the tasks under execution has been good. Again, that is with the proviso that some of the tasks seem divorced from the ultimate engine needs.

Reviewer 8:
The project is clearly on track, even with the COVID-19 pandemic. The reviewer thought the technical accomplishments are sound, but again, struggled to understand how this fundamental knowledge will be impactful to the application.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There is outstanding collaboration between participating National Laboratories and universities. This was also evident during the periodic stakeholder conference calls.

Reviewer 2:
The efforts by the team members are using complementary characterization methods. Members appear to be sharing and co-analyzing results and are working across the VTO and BETO sponsor organizations. The blend octane number predictions via neural net are very interesting and potentially valuable.

Reviewer 3:
The reviewer observed strong collaborations across National Laboratories. Based on the slides presented, it seems that there are some universities that participated in this project. However, it is not very clear what their roles are. The reviewer hoped their contributions can be included in the “Technical Accomplishment” slide to be clear.

Reviewer 4:
The team coordinates work between nine National Laboratories and university laboratories to perform this work. There is outstanding coordination within the team to get the work done. In the future, when LLNL wishes to validate its blending models, there is enough expertise in the team to do so.

Reviewer 5:
It appears that the partners are well connected and collaborating appropriately.

Reviewer 6:
The various moving pieces do seem well coordinated within the teams. The reviewer would like to see significantly more teaming with some of the experimental groups that can show the significance of this work. The Engine Combustion Network (ECN) groups are studying sprays; can this team link with them to show that the fundamental work here is relevant to the experimental results that they see? The engine combustion groups have the ultimate test: to find out if the engine cared about some of the things this team is studying. This team needs to link with the ECN to show impact potential.

Reviewer 7:
Collaborators include nine National Laboratories, and four universities, but the reviewer did not see any collaboration with industry. The reviewer thought that having some industrial feedback would greatly help this project remain relevant to VTO and BETO goals for deployment.

Reviewer 8:
Each task has a number of external collaborations listed, primarily with universities, but there appears to be less coordination among the three tasks presented here.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer was glad to see that the work is planned to move toward linking the fundamental work to real spray and combustion phenomena. The reviewer thought that the quicker the projects can show links to spray and combustion behavior, the better; that will focus the further fundamental studies toward the right questions.

Reviewer 2:
The future work appears coordinated with the overall Co-Optima effort. The team responded well to reviewer comments from last year.

Reviewer 3:
The team very clearly identified the challenges, barriers, and limitations of the research at the current stage. Future research areas are well planned and aimed at solving the remaining challenges.

Reviewer 4:
The future research direction is crucial to the applicability of these fundamental studies. The team recognizes this and has planned 2021 work accordingly.

Reviewer 5:
The team proposes fundamental research to understand reaction species that explain phi-sensitivity and non-linear octane blending. This will be done by using machine learning to cluster simulated chemistry features to uncover hidden correlations between engine models and engine performance; conducting droplet vaporization simulations to realize the effect of HOV of alcohol blends on mixture stratification due to evaporation; and quantifying the effect of dilution properties on autoignition. This is the type of work National Laboratories should be working on, ones where they take on complex problems with unique research and expertise.

Reviewer 6:
The identified challenges, barriers, and proposed future research appear to lay a lot of emphasis on phi-sensitivity. While phi-sensitivity may be important for a particular combustion mode, some of the fundamental fuel property characterization being investigated by the sub-projects in this report can be significantly more impactful. For example, the reviewer suggested that improving fuel vaporization and spray development capabilities of engine simulation tools stands to have a much more substantial impact on automotive engines currently under development than phi-sensitivity. Improved spray modeling is critical not only for improving simulation of engine combustion but also soot formation, with the latter being a significant challenge that the automotive industry is currently working on addressing regardless of the type of combustion system. The team is encouraged to apply the fundamental understanding of fuel properties presented in the current report to improve the spray modeling and engine combustion capabilities of engine simulation tools.

Reviewer 7:
Based on what has been postponed due to COVID-19, it seems that the future work plans are solid, but the reviewer thought the impact of this work could be greatly improved by bringing in some more formal collaboration with the Coordinating Research Council (CRC) companies.

Reviewer 8:
NREL's (Task F.1.3.2) proposed future work—using simulations of evaporation, which have now been shown to predict the relevant azeotropic behavior to interrogate the impact of said phenomena on droplet evaporation in engine-relevant situations—is a great way to potentially transfer the fundamental knowledge gained through benchtop experiments.

LLNL's (Task G.1.1a) future work—using kinetic models to investigate phi-sensitivity and machine learning to search for correlations—is both a highly relevant and valuable endeavor. Particularly, the machine learning task addresses a shortcoming in current research the challenges of distilling complex multi-physics problems to controlling variables.

It is unclear how investigations into the relationships between distillation behavior and fuel octane ratings (Task F.1.2.5) will be conducted without significant partnerships with organizations that have been working on this topic for years (Argonne National Laboratory [ANL]).

The proposed work, "Develop methods to control and optimize fuel component vapor-liquid partitioning, through modification of distillation azeotropes…" does not provide enough detail, while the concept of tailoring autoignition properties through the tuning of azeotropic behavior is interesting but academic.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This research to provide fundamental understanding will aid future biofuel formulations for maximum utilization effectiveness.

Reviewer 2:
These efforts clearly support the overall DOE objectives. The reviewer believed that DOE should sponsor more fundamental research, like this project.

Reviewer 3:
Once the planned 2021 work is complete, the relevance will be very clear to the community. The reviewer encouraged the project team to keep up the good work.

Reviewer 4:
Improved fuel property characterization is essential for enhancing the capabilities of engine simulation tools and, in the process, helps accomplish the DOE's goal of improving engine and vehicle efficiency.

Reviewer 5:
Without understanding the effects on non-linear octane blending and how it changes phi-sensitivity, it will be extremely difficult to operate engines using LTC regimes.

Reviewer 6:
The reviewer believed that the work is relevant to the more fundamental goals of Co-Optima.

Reviewer 7:
The tasks presented here are relevant to overall DOE objectives of delivering knowledge to industry that supports improving the efficiency of internal combustion engines and reducing the consumption of petroleum. Both the fundamental phase-change phenomena and the prediction of fuel properties support these goals.

Reviewer 8:
Within the context of the Co-Optima program and its support of DOE objectives, this project does play a role. The reviewer tended to think it is biased a little too far to the fundamental, or, at the very least, it is not well communicated how it ties to the engine engineering side of the program. As the teams can show how this work impacts real engine behavior, then the project can be more and more relevant toward DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
For the work being done, the budgets seem quite reasonable for the work plan and output.

Reviewer 2:
The team has sufficient resources to achieve the stated milestones in a timely fashion.

Reviewer 3:
The team appears to have resources appropriate to the tasks.

Reviewer 4:
The funding is sufficient for the proposed work.

Reviewer 5:
Based on the progress of the team and the extensive research capabilities of the team, the resources appear to be satisfactory.

Reviewer 6:
The resources seem sufficient.

Reviewer 7:
The funding appears on the low end of sufficient, considering the team size and progress.

Reviewer 8:
The project ambitions, indicated by the goals and proposed future work, are not fully supported by the resources devoted to the project.

Presentation Number: ft069
Presentation Title: Multi-Mode: Fuel-Property Impacts and Limitations on Combustion–Spark Ignition Focus
Principal Investigator: Derek Splitter (Oak Ridge National Laboratory)

Presenter

Derek Splitter, Oak Ridge National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 86% of reviewers indicated that the resources were sufficient, 14% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

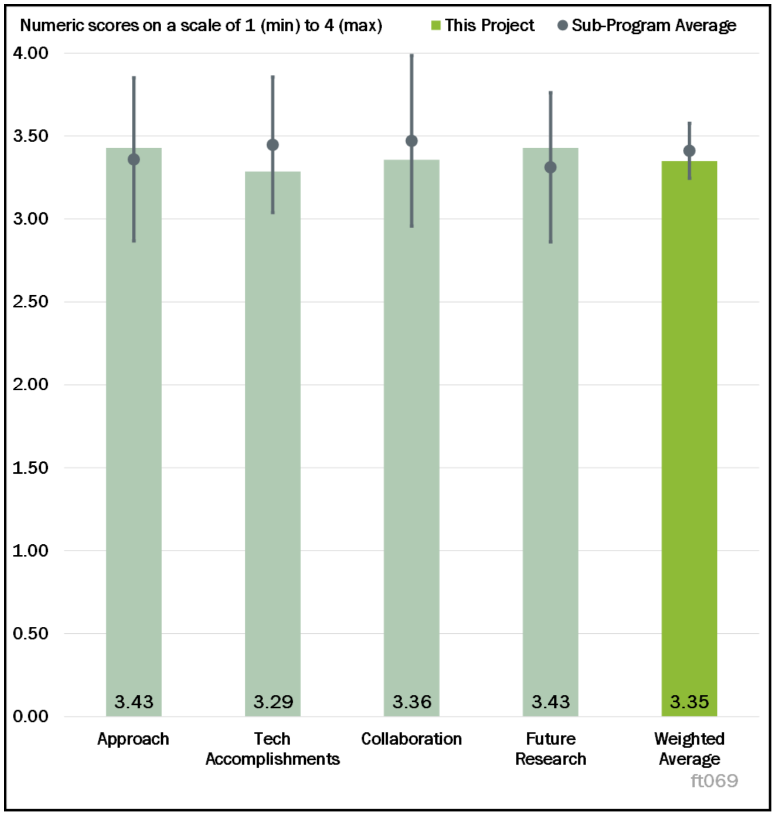

Figure 5-3 - Presentation Number: ft069 Presentation Title: Multi-Mode: Fuel-Property Impacts and Limitations on Combustion–Spark Ignition Focus Principal Investigator: Derek Splitter (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach is excellent. The researchers are covering a considerable number of factors that could affect the limitations of MM combustion in SI engines. The engine and spray work is impressive.

Reviewer 2:

The team leverages multi-cylinder engine (MCE) experiments, CFD modeling, and single-cylinder engine (SCE) work to explore advanced strategies to mitigate knock and increase fuel tolerance of ACI MM combustion. Overall, the project is well scoped. The goal of the CFD work should be better explained, especially how it will support the SCE and MCE work.

Reviewer 3:

The combination of knock mitigation work with ACI fuel tolerance is logical and drives well at the technical barriers.

Reviewer 4:

It is very encouraging to see that the project team is directly trying to address barriers identified by the automotive stakeholders. Doing so increases the likelihood of the ongoing and proposed research to contribute to development of production engines and thus be implemented in mass market applications. The topics being investigated in this project (impact of MON, low-temperature heat release [LTHR], spray modeling, and low-speed pre-ignition [LSPI]) are very relevant for current and near future engines, and continued research in these areas is strongly encouraged. The MON/octane sensitivity (OS) investigation should consider exploring higher engine speeds at elevated intake air temperatures, as these conditions are relevant for both peak power and heat rejection. As none of the other questions cover this, the reviewer is including this feedback as part of this response. The current presentation has insufficient description of operating conditions on most plots, which makes it harder to assess/appreciate the significance of the data being presented. Kindly consider specifying the operating conditions either on the plots or in backup for future presentations.

Reviewer 5:

The primarily experimental approach outlined here, with kinetic modeling support, will deliver highly relevant data on the impacts of fuel properties on the range of operation of conventional SI and ACI operating modes, as limited by knock (or ringing), as well as other unidentified phenomena that may be challenging to predict through modeling. In particular, the upgrade to the General Motors (GM) SG2 head will improve the relevance of the ACI results.

Reviewer 6:

There are lots of different tasks here, but they are broadly very well tied to end impacts of Co-Optima. The work is providing valuable insights into the impact of fuel chemistry as well as gross properties. Simulation comparisons to the experiments also bring value to validate the simulation quality and demonstrate how to effectively use the simulations. The reviewer is less enthused with the stochastic pre-ignition (SPI) studies as presented here. There are some new details to be sure, but the broad results are more or less covered in the current literature on the phenomenon. It would be helpful to see what the end goal of the SPI work is, and how it is distinct from all the work done to date in that area.

Reviewer 7:

First, the reviewer found it really important to note and emphasize that it is really difficult to do a comprehensive review of the projects in this presentation because there were just too many included to allow for time to go into any depth of description. The reviewer strongly disliked this approach to reviewing these projects. When you are talking about large amounts of money and complex science, this “mash up” approach does not do justice to the work.

The approach to this work is based in experimental evaluation of the Co-Optima core fuels under real engine (not just SCE) operating conditions. Due to this realistic evaluation of the fuels, the reviewer knew that simple fuel properties are insufficient for determining their performance (no easy answer) (regarding the ORNL engine projects.

The ANL sprays work is really too young to review yet if it started late in 2019.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer’s comments here are similar to those for Question A. The investigation of MON effects on power density is of high value; if fuels were to change to accommodate ACI, there still needs to be consideration of the fallback to more conventional operation. And separating the details of fuel chemistry and octane is of high value. This is work that both supports future ACI efforts, but also supports current industry efforts to increase conventional SI combustion. There could also be value to the general aviation community and the ongoing efforts to get rid of 100 Low Lead (100LL) fuel from the market, but the failure to date is in finding a good alternative. If some of the chemistry work here were communicated to those in the aviation world, there could be some nice knock-on benefits.

Reviewer 2:

The team has made very nice progress. The work related to CFD should be accelerated to catch up to the other activities.

Reviewer 3:
The technical accomplishments seem on pace for this investigation. However, it can be difficult to assess due to the wealth of parallel avenues presented at once. There is usually only a couple of minutes discussing the technical content and singular slides representing the congruous contributions from all other portions of the project.

Reviewer 4:
This project has made excellent progress over the past year. Some of the notable accomplishments of the project include:

- Impact of MON on knock resistance
- Impact of fuel composition on LTHR under different operating conditions
- Improved spray modeling and combustion simulation to help investigate LTHR
- Better understanding of the impact of fuel volatility on LSPI/SPI.

The excellent match between experiments and simulations for spray pattern and penetration and the combustion process/pressure profile is quite impressive. It is unfortunate that the PI was limited by resources, as the SPI response of low volatility fuel under different operating conditions (higher load) would have provided further insight into the impact of volatility and oil additives (Calcium [Ca]) on the likelihood of SPI occurrence. The PIs are encouraged to include quantifiable performance indicators in future reports in accordance with DOE guidance to reviewers for evaluating projects.

Reviewer 5:
This reviewer really liked the work that is being done here. The reviewer would have given the projects a higher mark; however, the SPI chart on Slide 17 shows that there is no statistical significance between the data. From the looks of it, the data could have used a larger data set. There is significant clustering of the data to show trends, but the whiskers in the box and whisker-plot overlap are indicating a need for more data to reduce the error. The reviewer wished the rating would allow more granularity, as the lack of data looks to be from insufficient funding of the engine testing.

Reviewer 6:
There is clearly significant progress being made in the engine projects; however, it is clear that the barriers are significant and there are persistent issues that are difficult to overcome. Additional work is clearly needed.

Reviewer 7:
Investigations into the effects of a fuel's MON rating on high-speed high-load operation are promising, but have not yet covered a range of fuels and compression ratios such that this question can be put to rest. The results shown from SCE investigations into autoignition behavior provide a baseline for future work in this engine platform, however, the results shown here replicate prior results and have not progressed to providing new insights.

Engine modeling results demonstrate reasonable agreement with the experiment in two of the three validation cases shown, but the "Strong pre-spark heat release (PSHR)" case exhibits significant differences in flame propagation between the experiment and the model that will need to be addressed before investigations into fuel-specific phenomena can begin.

LSPI investigations hold promise but the results shown here have not yet advanced the state of understanding beyond what is available in the literature.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer sees excellent collaboration and coordination with other laboratories and universities, and very strong ties to industry. The strong participation in the Advanced Engine Combustion (ACE) Memorandum of Understanding (MOU) and the strong corporate support is excellent.

Reviewer 2:
This reviewer is impressed with the level of collaboration that has been going on during the entire AMR. This specific project has an impressive list of experts in the engine and modeling fields.

Reviewer 3:
Excellent collaboration between participating National Laboratories and industry stakeholders.

Reviewer 4:
The collaboration across the project teams appears to be fine. The reviewer wonders the reason that it took so long of making the engine data available to ANL for the CFD work. The project gained support directly from auto and oil industries, showing excellent relationship and collaboration.

Reviewer 5:
The apparent level of collaboration and coordination varies across the project team. Demonstrated examples of collaboration include the engine modeling task, which combines experimental data from multiple sources (engine data from ORNL and spray data from Sandia National Laboratories [SNL]) to support the task. Another positive example is the connection between experimental autoignition studies in engines and the kinetic-modeling task.

Reviewer 6:
In general, the team is appropriately collaborating amongst the working group. However, it was unclear if a distinct collaboration between the ACI autoignition sensitivity changes and the other groups working on fuel chemistry/kinetics impacts exists.

Reviewer 7:
This is an odd assemblage of projects to look for collaboration. They are generally on separate engine platforms and investigating different topics within the broad topic area. The reviewer was sure the PIs are coordinating well since most of them are at one lab, but did not see any meta-narrative that says how the findings from the various tasks come together.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The project team very clearly identified the challenges, barriers, and limitations of the research at the current stage. Future research areas are well planned and aimed at solving the remaining challenges. The team should consider how the results of this work can be better transferred for future engine development.

Reviewer 2:
The future work plan seems appropriate based on the barriers to be addressed.

Reviewer 3:
The project has made excellent progress thus far, and continuation of several of the ongoing efforts is encouraged. For example, there is growing evidence that fuel particulate matter index (PMI) is not only important for engine-out particulate emissions but also the propensity of SPI occurrence. Investigation of the

impact of PMI on SPI occurrence is strongly encouraged. Improving the CFD capabilities to model fuel spray, evaporation, and combustion (including LTHR) is also strongly encouraged.

Reviewer 4:
The proposed future research appears to be comprehensive. The reviewer would only suggest that the SPI testing have more data points and that follow-up with the engine testing be performed.

Reviewer 5:
This reviewer particularly looked forward to the multi-cylinder SI work, as it will become more translational to the application.

Reviewer 6:
The proposed future research collectively addresses a number of particular challenges identified by the United States Council for Automotive Research (USCAR) and Co-Optima, including the applicability of fuel properties such as PMI to LSPI, and the response of fuel-dependent, low-temperature autoignition reactions to lean operation.

Other proposed work seems duplicative; for instance, "Extension of the pressure-temperature (P-T) analysis framework to consider in-cylinder…" already exists within the literature and within the DOE national laboratory complex.

Reviewer 7:
Again, the different tasks end up with different grades here. The study of LTHR and SI versus ACI operation is great; this is foundational stuff that will be required for any future engine development. The CFD work is also well tailored to future R&D needs. The P-T analysis is fascinating stuff, though the reviewer still struggled to follow it well when watching a fast presentation. On the other hand, the SPI work is less valuable looking to this reviewer's eyes. The industry has spent some time looking at fuel effects on SPI, and there are publications looking at some of those effects. The biggest challenges to SPI with respect to fuel are generally that the OEM will not have any knowledge of or control over the fuel that goes into the engine (particularly when the industry talks about global fuel markets). Therefore, OEMs will remain constrained to hardware designs that are tolerant to worst-case fuel scenarios. This reviewer was not sure exactly what to recommend instead, but did not think the plans as stated are all that valuable, especially within the context of ACI.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Broadly, these tasks are well aligned with DOE objectives to demonstrate technologies for improved fuel economy.

Reviewer 2:
This project aligns with DOE objectives and Co-Optima goals.

Reviewer 3:
The project is well aligned with overall DOE objectives to advance the efficiency of vehicle engines.

Reviewer 4:
The research topics undertaken as part of this project are extremely relevant, not just for MM combustion but for conventional SI engines as well.

Reviewer 5:
The issues being investigated by the research team are significant barriers to the impact of MM combustion. By understanding the effects of fuel properties on MM combustion efficiency, improvements can be made.

Reviewer 6:
Knock mitigation is probably one of the most key issues to internal combustion (IC) engine efficiency—so this project is highly relevant.

Reviewer 7:
The projects and tasks shown here directly contribute to the understanding needed to design the next generation of engines and fuels, leading to reduced fuel consumption and greater utilization of resources.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The budget seems adequate for the work performed and work proposed.

Reviewer 2:
The team seemed to have adequate resources.

Reviewer 3:
The project funding appears well aligned with the project scope and milestones.

Reviewer 4:
The funding is sufficient for the proposed work.

Reviewer 5:
Resources appear sufficient.

Reviewer 6:
The projects are adequately resourced, allowing significant effort to be devoted to the tasks, which is in alignment with their importance.

Reviewer 7:
On Slide 17 the data appear to be statistically insignificant. From the reviewer's experience, this is an effect of too few data points. This can be eliminated by running more tests because a clear trend can be drawn from the data.

Presentation Number: ft070
Presentation Title: Multi-Mode: From In-Cylinder Combustion Diagnostics to Drive-Cycle Fuel Economy
Principal Investigator: Magnus Sjoberg (Sandia National Laboratories)

Presenter

Magnus Sjoberg, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 20% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

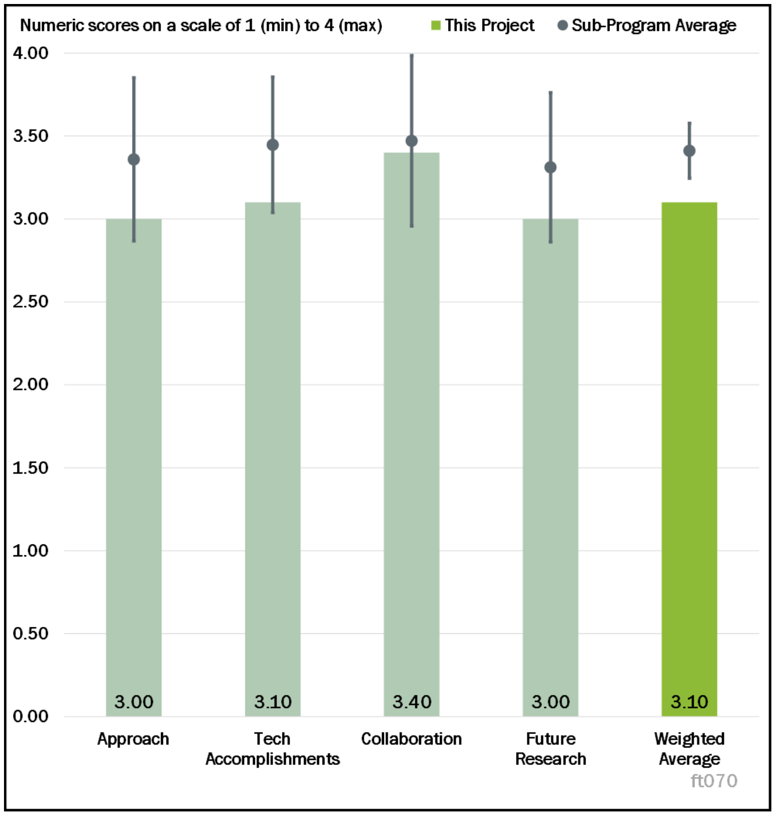

Figure 5-4 - Presentation Number: ft070 Presentation Title: Multi-Mode: From In-Cylinder Combustion Diagnostics to Drive-Cycle Fuel Economy Principal Investigator: Magnus Sjoberg (Sandia National Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The team has an outstanding approach using both metal and optical engines along with computational analysis.

Reviewer 2:

The approach in this project is pretty good—there is experimental and simulation work that appears to support each other nicely—but the overall goal of the project seems a bit unclear. If the intent is to explore MM combustion systems for an LD engine, there needs to be a determination made about whether the overall engine will be stoichiometric or lean. The aftertreatment requirements are quite disparate, and there is no way that any potential benefits of a part-time stoichiometric/part-time lean system will not be consumed by the horrific cost and complexity of two aftertreatment systems. As mentioned in one of the questions, the target needs to be ultra-low nitrogen oxides ($ULNO_x$) compliance, not current NO_x compliance. There needs to be a better case made for why this MM approach is going to provide benefits in efficiency or operational use compared to simply hybridization or electrification.

Reviewer 3:

The reviewer was not sure how, or if, the knowledge from these research efforts is advancing the knowledge of MM combustion relative to what industry already knows. The reviewer would happily change this comment if the research questions being investigated here were shown to have been developed in collaboration with an industry group like USCAR, for example.

Reviewer 4:
The connection between yield sooting index (YSI) study and piston top fuel film formation to mixed-mode ACI combustion is unclear.

There is also a range of different combustion approaches explored in the work, and understanding fuel effects on the specific mode is a focus and clear outcome. However, the reviewer highlighted the following key challenges with mixed-mode operation:

- Optimal fuel properties for the advanced combustion portion of the cycle may differ vastly from those being used in the conventional portion, and understanding this impact is critical to the success of a mixed-mode concept.
- Multiple combustion modes require a transition between operating strategies, and operation through that transition may compromise performance and ultimate capabilities of the advanced combustion mode.

These are the central challenges of mixed-mode, but seem to be largely absent from the direction of the work. For any concept to be practical for commercial adoption requires that its operation meets relevant emissions targets. Including required aftertreatment considerations should be fundamental to any advanced combustion strategy evaluation.

Reviewer 5:
The approach taken at SNL is mostly sound, with the investigations of YSI as an alternative to PMI to understand sooting and particulate matter emissions from lean stratified charge engines with oxygenated fuels. However, pursuing the prediction of fuel economy with Gamma Technologies Power (GT-Power) and Autonomie with the results obtained from the SCE, with no rigorous engine-out NO_x control, may have very little value. This task is best left to the OEMs, which is their strength.

The purpose of efforts at ANL and LLNL is not clear. Is there any indication of what fuel property enables spark-assisted compression ignition (SACI) type combustion? Other than the OS of the fuel, the reviewer asked whether the fuel properties for SI boosted operation and HCCI combustion conflict with each other. LLNL's finding—via 80,000 fuel simulations—that high RON and high OS enable high load operation has been known for a long time.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The team has made great progress to date.

Reviewer 2:
The progress in this project has been noticeable and has merit. In particular, the model improvement for speed and accuracy and the optical diagnostics that identify soot formation characteristics based upon fuel properties is impressive. But, the challenge of MM is to determine when the engine should be operating in which mode and under which conditions. The work done here should help define that approach, but it appears to be a bit incomplete. The project has made substantial progress in understanding soot formation but cannot decide whether it is stoichiometric, lean, or dilute, or how large the operating range should be for each combustion mode. When this reviewer looked at potentially using this MM approach, it appears that the challenges are greater than the potential improvement can overcome. Idle reduction, low load cycle, $ULNO_x$, and GHG regulations all combine into forcing OEMs to adhere to a coherent strategy for operating the engine. This work has made some progress toward that goal, but the project needs to re-define what the desired outcome should look like.

Reviewer 3:
Overall, the work is very good. The sensitivity analysis being done at ANL has the potential to be very useful, but would carry much more impact if it could be verified experimentally.

The work at LLNL on fuel robustness includes an adjustable parameter in K, an empirical "constant," which is part of the octane index (OI). K changes with engine operating conditions, and even such things as differences in the fuels' HOV can bring about changes in K. As a result, the reviewer did not know how to interpret the results of this effort.

The observation that the PMI has a dependence on vapor pressure of the fuel is not all that surprising. However, trying to include this in any correlation for calculating the PMI of the fuel will now make the modified-PMI a function of the engine in which the fuel is being used, as the fuel's vapor pressure, in combination with the engine hardware, geometry, and operating condition, will impact the distribution of the fuel vapor within the cylinder and the propensity for the formation of liquid films in the cylinder.

Reviewer 4:
The project is delivering significant research output, for which it is to be commended, and is in line with the level of funding received. However, it is not obvious that the work is making quantifiable progress forward to enabling mixed-mode combustion in LD vehicle applications. The project needs to be clearer about how the simulation work will ultimately support the effort. Validation of CFD models is a required baseline step in the development process, but it is important to highlight how these will be used to enable, and further understand, fuel property impact on mixed-mode operation. The reviewer noted that the two CFD-related milestones, model validation and data transfer, are process milestones. Moving forward, these milestones should be prescribed in a way to demonstrate progress against key barriers in understanding mixed-mode operation.

Additionally, CFD results for parameter sweeps were indicated as not having been fully validated with experiments. This is something critical to resolve to ensure that results being generated have value.

Finally, modeling of the fuel economy gain with MM operation needs to include a real penalty associated with both the transition between operating strategies and the emissions control required to deliver tailpipe emissions meeting regulatory standards. For advanced combustion concepts, this is an absolutely essential part of the equation. Results that do not include this, especially the emissions control factor, are meaningless.

Reviewer 5:
Lots of work has been done, however, as mentioned above, the value or impact of the work may be less than desirable. For example, in the work at ANL, partial fuel stratification (PFS) has been added to the recipe of SACI. This has made the combustion more complex and dependent on more control parameters. Was the injection quantity and timing of the late pilot injection varied to test the effect of phi stratification on end-gas autoignition? When does soot become an issue with the late injection?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This is an excellent example of how to run a collaborative effort. They have brought in excellent industrial partners as well as laboratory partners.

Reviewer 2:
As is typical of most Co-Optima teams, this project appears to be fairly well coordinated among team members and among different aspects of work—engine experiments, benchtop experiments, and simulation. Communication and coordination appear to be rather good.

Reviewer 3:
The collaboration with this project is excellent. The reviewer hoped that there was close interaction with industry stakeholders as to what they believe are the technology and fundamental barriers that, if solved, would facilitate moving MM operation into the market. It was not clear in the presentation if this is the case.

Reviewer 4:
Good collaboration exists among SNL, ANL, and LLNL.

Reviewer 5:
There appears to be reasonable coordination across the project team, with transfer of information between simulation and experimental activities. There is significant collaboration in areas of fundamental science between project members and other parties. The reviewer encouraged more connectivity with other advanced combustion researchers and automotive R&D organizations to ensure the approach to the project aligns with the key barriers and requirements for mixed-mode operation. Some of the shortfalls highlighted in this year's results could have been avoided with the right connectivity and input earlier in the process.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Within the stated goals and established projects for this program, the future research is well laid out.

Reviewer 2:
The approach is outstanding, but there is one particular missing aspect that this reviewer hoped can be addressed. For the vehicle simulation work, the reviewer expressed interest in the team doing two things: run the simulations with some emissions constraints given an engineering estimate of how much NO_x and particulate matter (PM) you could tolerate in a production engine; and run the simulations as well with some hybrid powertrains to avoid some of the problematic regions and with even more heavily downsized engines.

Reviewer 3:
There is significant variation and scatter in the LLNL work, but it is focused on low-component-number surrogate fuels. If possible, this should expand to look at more market representative fuels. The reviewer noted that the CFD simulation activity should have an increased focus on delivering results and an increased understanding of fuel property effects rather than further refinement of the models. Overall, the project needs to sharpen its focus onto the key challenges with mixed-mode combustion, and how fuel properties can be used to reduce those barriers, enable operation, and improve overall operating efficiency across all operating regimes.

Reviewer 4:
In the time remaining for Co-Optima 2.0, work at all three labs should concentrate on how the results and findings so far change when engine-out NO_x emissions are constrained (with exhaust gas recirculation [EGR] or other techniques) to make the lean aftertreatment cost effective.

Reviewer 5:
The most important question to be addressed is whether this will be a lean or stoichiometric combustion system in MM. They are fundamentally different and will require OEMs to utilize them in fundamentally different ways. Any future work that relies upon stoichiometric operation at high load and lean LTC operation at lower load is essentially a non-starter. The aftertreatment disaster alone will disqualify this approach; in particular, having enough exhaust energy at low load to keep selective catalytic reduction (SCR) functional in a lean environment to meet $ULNO_x$. The rest of the future work appears to be reasonable insofar as following

up with current success, but the overall intent of the project has a major flaw that must be addressed and is not explicitly addressed in the future work slide.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Yes, this project does support overall DOE objectives.

Reviewer 2:
Establishing the simulation capabilities for fuel characteristic optimization to identify potential enhancements to MM operation is a relevant objective for DOE.

Reviewer 3:
The project, if focused on the key challenges of mixed-mode operation, does support the DOE objectives for increasing efficiency of, and reducing emissions from, vehicle transportation.

Reviewer 4:
The project fits the DOE goals to improve engine efficiency.

Reviewer 5:
This project aims to reduce petroleum usage and GHG emissions.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources are sufficient.

Reviewer 2:
There was one statement in Slide 4 that resources were not sufficient to complete the task. No explanation was given. Other than this, it seems that the resources are sufficient.

Reviewer 3:
The scale of this effort is larger than other, similar projects. The combined scale of SNL funding is significant.

Reviewer 4:
The resources are sufficient.

Reviewer 5:
The resources are sufficient and can be focused more on high-impact issues.

Presentation Number: ft071
Presentation Title: Multi-Mode Operation in Gasoline Direct-Injection Engines: Fuel-Property Effects and Approaches to Expand the Advanced Compression-Ignition Range
Principal Investigator: Toby Rockstroh (Argonne National Laboratory)

Presenter

Toby Rockstroh, Argonne National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers indicated that the resources were sufficient, 17% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

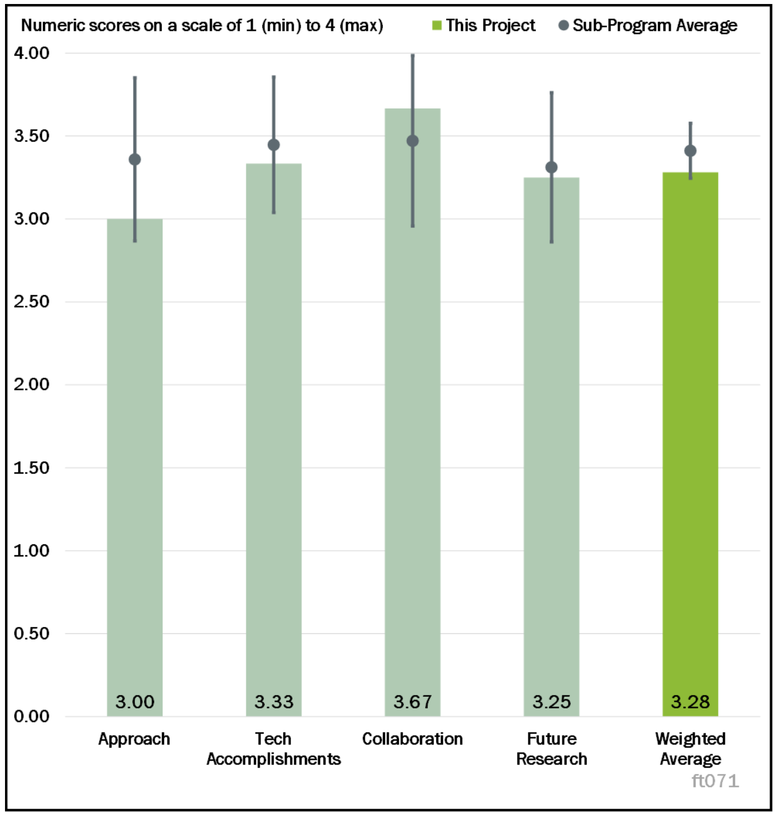

Figure 5-5 - Presentation Number: ft071 Presentation Title: Multi-Mode Operation in Gasoline Direct-Injection Engines: Fuel-Property Effects and Approaches to Expand the Advanced Compression-Ignition Range Principal Investigator: Toby Rockstroh (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

LD MM engine operation offers practical, near-term fuel economy gains over a significant operating map. MM operation consists of low-load ACI and high-load boosted SI. Challenges for MM operation include ACI operating-range combustion and control strategy challenge; strategies needed to enable SI/SACI transition; and maintaining high-load boosted SI operation. This project utilizes engine experiments and high-fidelity CFD modeling approaches to characterize fuel property effects and operating strategies to enable MM engine operation. The researchers' approach to the work is outstanding.

Reviewer 2:

The technical approaches used are good and linked nicely across the tasks to address the barriers to ACI combustion. Particularly of value is the effort to understand the mode-switching operation between ACI and conventional combustion. The work to develop methods for control schemes is also valuable, as combustion control remains one of the biggest challenges for implementing ACI.

Reviewer 3:

The combined modeling and experimental approach appears well aligned and feasible. There are several good investigations crammed into this 20-minute presentation. It is difficult to assess the details of the approach for several collaborative thrust areas in such a condensed format. This was clear during the question and answer (Q&A) immediately following the presentation. The questions asked would have been clearly explained by the presenter if given enough time to provide an overview of the underlying science and methodology when presenting the accomplishments.

Reviewer 4:
While the presentation identifies the technical barriers that the project tries to address, the link between the described work and the technical barriers is not established very well. For instance, it is not clear how the work focusing on estimating start of combustion will be used to develop methods to extend the limits of LTC. Also, a lot of effort seems to have been spent on correlating the rapid compression machine (RCM) ignition delay data and the chemical-kinetics-based ignition delay estimated using the Livengood-Wu (LW) integral. It may be convenient to use, but is the LW integral the appropriate tool/correlation for this task? There seems to be a lot of effort trying to account for the relatively large errors in the LW based ignition delays. Perhaps the errors are a consequence of the limitations of the LW integral.

The graphic on Slide 9 seems to indicate that the plan is to implement an active pre-chamber in the SCE. However, the material presented corresponds to a passive pre-chamber. The distinction between the planned work and work that has been conducted is not very clear. Additionally, it is not clear if/how the CFD models for MM/ACI combustion will be validated against experimental data. While some evidence has been provided of the ANL model being validated against engine data, there is no mention of corresponding engine data for the ORNL model. While both models appear to be very promising tools for evaluating MM/ACI combustion, it is critical to ensure they are validated against engine measurements.

Reviewer 5:
While it is technically and academically interesting to investigate SACI performance with pre-chamber hardware (Task E.1.2.5), it is unclear how the technical approach used in these experiments will lead to advances in achieving ACI and mode-switching strategies.

The approach of using CFD models (Task G.5.5) to run sensitivity studies can be useful. However, it requires intelligent design of the tested conditions with control over key parameters (combustion phasing, knock, emission) rather than a randomized or parametric approach, which previous research programs have shown to mainly result in exploring irrelevant engine operating conditions. Further, for a model to be useful over a wide range of conditions (e.g., the various combustion modes and conditions that are intended to be tested here), it must be shown to capture the key trends and associated conditions, which are currently the state of the art for CFD models. Therefore, that raises doubt as to whether the approach taken here will truly be able to contribute understanding of the wide range of fuel-property and engine interactions that are envisioned here.

Reviewer 6:
The industry focus areas are fuel economy and emissions and a specific look at CO_2 reduction. It is unclear where the project team thinks this is headed. "Panning for gold" was indicated by this reviewer, who explained that, basically, the project is developing an engine concept and seems to be using the Co-Optima fuel set to determine how well it works. Did this reviewer miss the part where the project team did a fuel property sensitivity study? It is not clear what the learnings provide to help implement the combustion system and mode switching. It would help if the team could show how the modeling work predicted an improvement, and then verify with an engine experiment.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The team has had significant breakthroughs in both modeling the ignition and engine performance in MM operation as well as modeling the transition from ACI to SI.

Reviewer 2:
It appears that a lot of progress has been made in all of the tasks. Other than the COVID-19 delays, the team appears to be well set for achieving the project goals.

Reviewer 3:
All thrust areas of the project appear to be operating at pace for successful project completion.

Reviewer 4:
A significant amount of work has been conducted in each of the covered sub-projects. However, it appears a majority of the work thus far has been in establishing the tools/experimental setups that will be used for work to be conducted over the next year. This reviewer looked forward to observations and conclusions drawn from the work proposed for these projects. Based on the data presented, it appears the passive pre-chamber investigated did not help extend the operation limits for MM combustion. It will be interesting to see if the active pre-chamber enables MM operation over a broader operating regime.

The PIs are encouraged to include quantifiable performance indicators in future reports in accordance with DOE guidance to reviewers for evaluating projects.

Reviewer 5:
The technical accomplishments were solid, but the reviewer just struggled with understanding their relevance. The reviewer thought this was a casualty of the number of projects that were crammed into a single presentation. It made it difficult for the presenters to go into any kind of detail to set the scope of the impact of the work.

Reviewer 6:
The investigations into the predictive power of the LW integral under ACI conditions shed insight into the challenges of using this technique for quantitative predictions, particularly under lower-temperature, higher-pressure conditions where the autoignition event is influenced by first-stage and negative-temperature coefficient (NTC) chemistry. The use of a pre-chamber for ACI/SACI ignition is interesting and an appropriate way to generate relevant in-cylinder thermodynamic conditions for ignition studies with novel and high-performance fuels. However, the use of an unfueled pre-chamber has significant limitations, as shown in the results presented here, and makes achieving relevant conditions challenging.

Additionally, the CFD results from Task G.1.1.1 show surprisingly good agreement with experimental results. What has been learned from the work so far?

This reviewer opined that presented results from Task G.5.5 are worrying. When studying fuel-engine interactions, it is important that relevant engine platforms, combustion modes, and fuels are used in conjunction. When they are not, the results may not reflect the controlling physics found in practical/optimized combinations of hardware and fuels. The results show that a Ford 1.6-L SI engine was used for investigations, which is certainly appropriate for SI, lean SI, and perhaps HCCI with light stratification. However, extending the investigations all the way to MCCI combustion does not make sense, as the PI realized. While this poor pairing of hardware and combustion modes has been halted, even the partially premixed compression ignition (PPCI) mode is questionable, unless the model of the 1.6-L platform has been modified with a new injection system that delivers fuel appropriately under late-injection into hot and high-density conditions. Examining the results on Slide 16, the contour plots highlight a common problem with CFD explorations of operating conditions: most of the conditions shown here are irrelevant, either due to high-pressure rise rates (as can be expected for the overly advanced combustion phasing shown in the right-hand side figure) or low efficiency (likely due to incomplete combustion). What would be insightful would be to show the space of conditions that yield both high efficiency and low-pressure rise rate. Unless algorithms are used to ensure that the majority of investigated operating conditions are relevant (complete combustion, low-knock, low criteria pollutants), large explorations of input parameters will be a poor use of resources.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Excellent collaboration between National Laboratories, industry, and academia.

Reviewer 2:
The researchers are coordinating well between National Laboratories and within their labs.

Reviewer 3:
All three projects had strong and well-coordinated collaborations.

Reviewer 4:
These tasks are closely linked, and it does appear that the team members are coordinating well to have the experiments and simulations proceeding efficiently.

Reviewer 5:
While there was not time for the team to fully detail the collaboration between investigators within this study, the level of collaboration became increasingly clear during the Q&A discussing the LW modeling setup.

Reviewer 6:
Tasks E.1.2.5 and G.1.1.1 seem to have strong coordination with one another. Task G.5.5 does not seem coordinated with the other two tasks but does seem to have strong coordination across Co-Optima.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The future plans look effective to continue addressing the barriers associated with this program.

Reviewer 2:
The future work scope and timing appears appropriate to successful project completion.

Reviewer 3:
The proposed research is in line with the goals of the project and aimed at addressing the technical barriers that have been identified. The CFD modeling efforts are encouraged to validate the project team's results against experimental data to the extent possible.

Reviewer 4:
While the research into MM combustion is excellent, recent research suggests that when using the pre-chamber, if the nozzle hole is small enough, the combustion in the nozzle might be quenched and radicals that may better enable LTC combustion in the combustion chamber will be formed. Engine and modeling efforts may be directed toward this.

Reviewer 5:
There are significant remaining challenges for each project to continue to attack.

Reviewer 6:
The proposed fuel-property impact studies (Task E.1.2.5) are too broad, and it is unlikely that all of the properties listed will be able to be thoroughly investigated during the project duration. The proposed investigations of tradeoffs between lean- and EGR-diluted MM operation are highly relevant as the pre-chamber will allow relevant thermodynamic conditions to be created in-cylinder. Task G.1.1.1 modeling work

is on point and with a validated model will hopefully lead to practical insights. Task G.5.5 modeling work needs to be targeted at relevant conditions in order to deliver relevant results.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The tasks are well configured to support fundamental development of ACI engines.

Reviewer 2:
This project is clearly aligned with the DOE objective toward enhanced vehicle engine efficiency.

Reviewer 3:
This project is relevant in advancing the performance of MM engines that will further DOE's objectives.

Reviewer 4:
The investigations of interactions between modern engines and fuel properties will facilitate the design of new, high performance fuels (HPFs) that will improve LD vehicle efficiency by enabling advanced combustion modes.

Reviewer 5:
The proposed research is relevant for DOE's objectives of developing MM and ACI combustion. However, the included research projects are unlikely to result in near-term (less than 5 years) fuel economy gains as Slide 3 may be interpreted to suggest.

Reviewer 6:
It was difficult to understand this presentation and its impact. The reviewer thought the relevance bullet on the summary slide (Slide 21) is a blanket statement that could be put on every presentation at Annual Merit Review (AMR). The relevance on Slide 3 is much better.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The budget looks good for the work being performed.

Reviewer 2:
The level of resources appear sufficient and appropriate for the scale of activities in this project.

Reviewer 3:
Resources appear to be sufficient for the proposed scope of the project.

Reviewer 4:
The team has sufficient resources to complete its work.

Reviewer 5:
Resources seem sufficient.

Reviewer 6:
Tasks G.5.5 and E.1.2.5 are resourced appropriately. Task G.1.1.1 is under-resourced and should see more resources devoted to build on the well-validated model that has been developed.

Presentation Number: ft072
Presentation Title: Multi-Mode: Desired Fuel Properties for Advanced Compression-Ignition and Spark-Ignition Engine Performance
Principal Investigator: Chris Kolodziej (Argonne National Laboratory)

Presenter

Chris Kolodziej, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 20% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

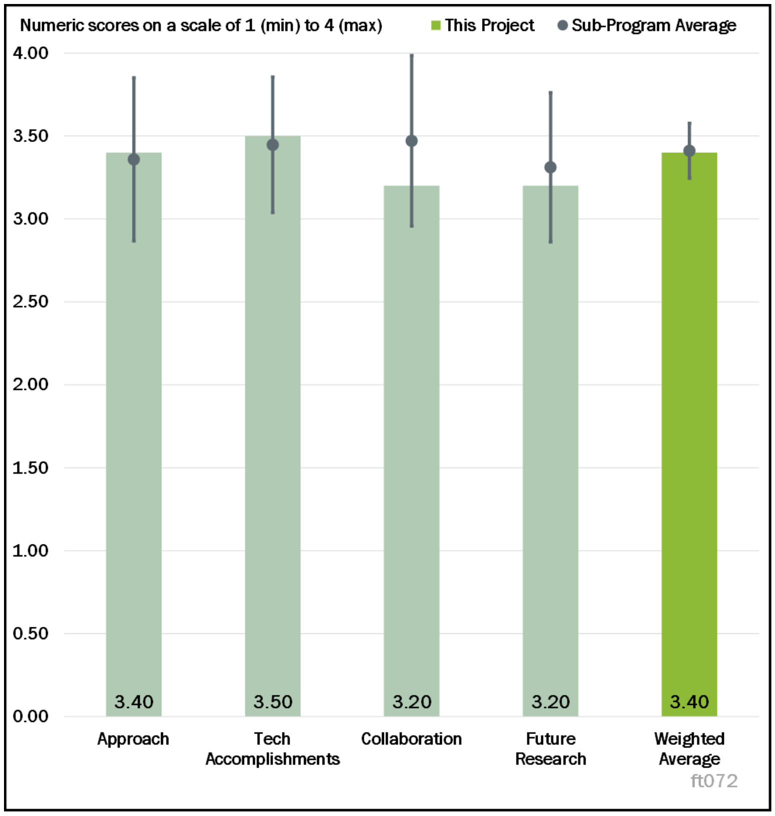

Figure 5-6 - Presentation Number: ft072 Presentation Title: Multi-Mode: Desired Fuel Properties for Advanced Compression-Ignition and Spark-Ignition Engine Performance Principal Investigator: Chris Kolodziej (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach to utilize a Cooperative Fuel Research (CFR) engine and a MD SCE, combined with simulation, makes a lot of sense. The CFR engine can provide very controlled engine conditions to study the fuel autoignition effects and the MD SCE should be able to expand upon those CFR engine results for more practical information. If zero-dimensional (0-D) modeling can be used effectively, this will aid greatly in technology transfer. This project also does a good job in understanding that lean/dilute combustion is likely the system of choice for MD/HD engines, and autoignition will likely be the only realistic choice for this class of engines in the future.

Reviewer 2:

The research is very thorough and being carefully carried out. It follows a systematic progression in attempting to answer the questions at hand.

Reviewer 3:

The team has already recognized that it needs to run additional gasoline-range fuels on the beyond-MON CFR engine.

Reviewer 4:

The approach is sound, and most of the work is directed at finding fuel properties that enable both boosted SI combustion as well as LTC at light loads.

Reviewer 5:

This combined set of projects is a very dichotomous effort. On one side, the ANL activity shows a clear path forward to understand and characterize fuels and their impact on operational barriers. On the other side, the NREL effort looks like it primarily used project funding to build a new engine test cell and has not made much progress toward evaluating fuel effects. This has also limited the effectiveness of the NREL modeling efforts. The NREL work is at a point where delivering the overall project results does not look feasible. The project timeline is more than 50% complete and slated to end at the conclusion of FY 2021. Yet, demonstration of ACI in the NREL SCE is not expected to be achieved until FY 2021. If ACI is not demonstrated until then, it is very unlikely that there will be any meaningful progress on delivering understanding of fuel properties or defining real optimal properties for MD and HD ACI in the remaining time available within this phase of the project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The team has made great progress to date considering how COVID-19 resulted in lab shutdowns for months.

Reviewer 2:

A substantial amount of progress has been made. The CFR engine has produced very impressive results in understanding the autoignition properties of various fuels and fuel components. The correlation with other engines in other locations is also impressive. It would also be helpful if this project were to incorporate some of the other groups' work in phi-sensitivity and incorporate that into the results shown here, along with the HCCI number or the proposed "supercharged octane number (SON)" number.

Reviewer 3:

The work at ANL particularly has made good progress with the quest for a new OI correlation with the CFR engine. It is not clear if the addition of another K (K_B) factor and octane number (SON) will help in the quest for a fuel that enables both modes of combustion. The effects of RON, MON, OS, and flame speed—work going on at NREL—is on target.

Reviewer 4:

The researchers have been very productive and bring the appropriate techniques and tools to bear in acquiring the data and doing the analysis. This reviewer believed that the fundamental explanations of the project's results are more complex than what the project team is proposing, as per statements made during the presentation. The use of the OI is an appropriate idea because it acknowledges that there is a link between the engine's temperature, pressure, and concentration-time histories and a given fuel's autoignition characteristics—through the competing kinetic pathways during the autoignition chemistry of the different fuels. The OI uses an empirical factor, K, to account for this. K was originally determined by a regression analysis, so it is, in essence, an empirical "constant." The reviewer thought this has led to confusion and sloppy use of K; there is not agreement within the field on what K really embodies. It is often treated as a constant when applied to a range of experimental data, such as in merit function calculations, for example. Slide 7 in this presentation may be an example of this sloppy use. The compression ratio is changed for each of the fuels in order to maintain a constant CA50. At the same engine speed, this will change the time rate of change for the temperature and pressure for each of the different fuels. The reviewer believed that it is a mistake to then state that the OI for each of the fuels in these tests is the same. The reviewer interpreted the statement that the Ks were equal, so fuels with the same RON and MON would have the same OI, ergo, a different assessment criterion for ranking fuels relative to ACI suitability was needed. This may be the case, but the reviewer did not believe these data specifically point to that. The data are interesting and important, but care needs to be taken in discussing its implication relative to the development of indices that will inevitably have implicit empiricisms.

Reviewer 5:
There are no real technical accomplishments or progress from the NREL efforts despite significant funding levels. The engine installation is in progress and the modeling development is in progress, but there are no clear fuel research outcomes. Validation of CFD models also needs further refinement if the results shown are representative of the current state. The simulations leave much to be desired in terms of replicating experiments since it does not look to be a very close fit, or accurately represents combustion details. The ANL work looks to be somewhat behind, but there are clear deliverables highlighted and significant progress along the two pathways focused on developing metrics for the ACI and conventional operation side of the mixed-mode strategy. Moving forward, the reviewer would encourage work toward seeing whether these two parameters could be incorporated into a single expression. A first step could be to visualize them as an x-y plot and see where different classes of fuels fit within the broader space.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer described the team as outstanding and reported nine labs and more than 20 partners.

Reviewer 2:
This project appears to have excellent collaboration and coordination among project team members. There is a sensible progression from CFR engine to Ford SCE and simulation work in between. This reviewer would have liked to see a bit more communication with the project working on phi-sensitivity; both sides would likely benefit from this. It is difficult to talk to everyone and also focus upon specific tasks; this is where effective project management and communication become critical. This is a strength of most of the Co-Optima teams, including this one.

Reviewer 3:
Based on one of the questions from another reviewer, this reviewer wondered if more communication with industry stakeholders, like USCAR, would be an additional collaboration worth considering.

Reviewer 4:
Little collaboration seems to exist across the project team. Given the lack of progress of one project, meaningful collaboration may not have been possible. However, external collaboration and coordination with outside parties appears fairly minimal and, on the surface, not overly significant. This subject area seems ripe for cross-laboratory collaboration, connecting the results from the CFR experiments to other mixed-mode projects running engines, as well as screening method development tasks and fundamental fuel-property analysis tasks at various outside laboratories.

Reviewer 5:
The details of the collaboration were not clear, but it looks like most of it occurs behind the scenes by industry and university partners.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
Most of the proposed future research is very relevant and natural extensions of current successes. One question is whether a gasoline direct injection (GDI) injector is the optimal way to study fuel stratification in a compression ignition (CI) engine? Is there a reason why a modified diesel injector was not chosen for the Ford SCE? Under boosted, high compression ratio operating conditions, there may not be much stratification possible with a relatively low-pressure GDI injector.

Reviewer 2:
The reviewer suggested considering a re-evaluation of the data discussion on Slide 7. Overall, future plans are good.

Reviewer 3:
It is concerning that remaining challenges and barriers appear much the same as they were at the start of this effort; that raises the question of how much closer the project is to resolving the project barriers. The ANL effort is on a good track to delivering meaningful results. The reviewer recommended to consider building from that project, drawing in other Laboratories and increasing the scale of focus on this task, which could help mitigate risk and increase the potential for impactful results in this area. This reviewer had very low confidence that the NREL effort will deliver meaningful results in the remaining project timeline, given that NREL has not demonstrated ACI operation in the engine yet and is not slated to do so until FY 2021. This effort needs robust controls and go/no-go milestones to ensure it can deliver progress, or reroute funding to other laboratories to deliver on a refocused effort.

Reviewer 4:
Going forward, other than the known conclusion that high RON and OS fuels enable boosted CI combustion, work should be concentrated on finding the kinetic behavior and fuel property(ies) that enable mixed-mode combustion.

Reviewer 5:
The reviewer questioned the results using the 6.7-L diesel Ford engine for a variety of fuels and making many conclusions. Gasoline-like fuels in CI are very sensitive to injector and piston design and engine calibration strategies. Is there any risk that the project team might make some false conclusions given a fixed hardware? How will the project team account for differences in fuel volatility affecting PM and NO_x if the team gets some localized rich regions due to poor hardware design?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Better understanding the autoignition characteristics and which fuel properties are influential is critical to making advanced combustion systems possible for MD and HD engines. This project definitely supports overall DOE objectives.

Reviewer 2:
Understanding the details of a fuel's structure and how it interacts with the thermodynamic time-histories the fuel experiences in the engine cylinder as it traverses through its autoignition chemistry is very important and relevant for DOE.

Reviewer 3:
The work is very relevant to DOE objectives.

Reviewer 4:
This project is aimed at reducing petroleum usage and GHG emissions.

Reviewer 5:
The ANL effort is aligned with the Co-Optima focus on understanding mixed-mode combustion, contributing to a larger program focus on improving vehicle efficiency and decreasing emissions. The NREL effort, appearing to be focused on acquiring new laboratory capabilities, has not demonstrated alignment with DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This project appears to have sufficient resources to make the necessary progress.

Reviewer 2:
There was no indication that the funding level was not sufficient.

Reviewer 3:
The resources seem sufficient to perform the tasks.

Reviewer 4:
Resources should be focused efficiently on identifying the fuel properties that enable LTC at light load, without deteriorating boosted SI combustion at high load.

Reviewer 5:
There has been significant funding for the NREL effort, markedly more than other activities, but very little results or forward progress on the specific research topic area. The focus appears to be developing a new engine test cell, and there already exist significant capabilities across the DOE lab space in this area. Although the ANL project has a proportionately small budget, it is demonstrating good progress. The reviewer suggested broadening the scope to include other laboratories, enabled by increased funding levels.

Presentation Number: ft073
Presentation Title: Co-Optima Emissions and Emissions Control for Spark Ignition and Advanced Compression Ignition Multi-Mode Combustion
Principal Investigator: Sreshtha Sinha-Majumdar (Oak Ridge National Laboratory)

Presenter

Sreshtha Sinha Majumdar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

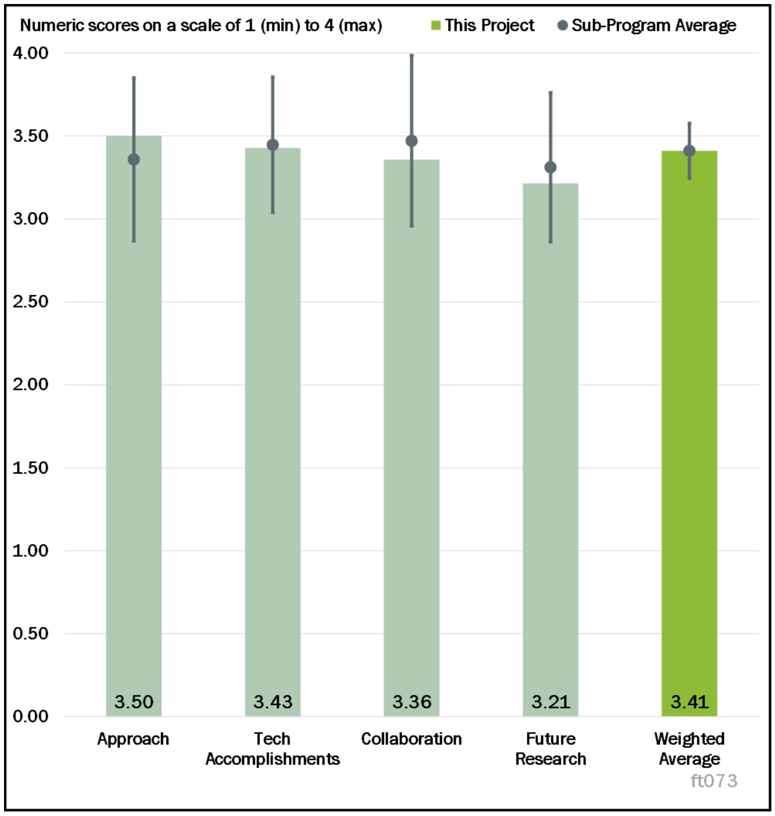

Figure 5-7 - Presentation Number: ft073 Presentation Title: Co-Optima Emissions and Emissions Control for Spark Ignition and Advanced Compression Ignition Multi-Mode Combustion Principal Investigator: Sreshtha Sinha-Majumdar (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
Emissions control for ACI engines is a critical barrier to commercial use; as criteria pollutant regulations become tighter, the low engine-out emissions from ACI will still be far too high for certification. These studies are well crafted to characterize the emissions as a function of fuel properties, chemistry, and engine operation. The tie to catalyst improvements then completes the picture for trying to address this critical barrier.

Reviewer 2:
The approach to evaluate the chemical and physical fuel impacts on emissions is logical.

Reviewer 3:
The approach to each of the sub-projects discussed this year, (1) Task E.2.2.7 (ORNL), (2) Task E.1.3.1 (ORNL), and (3) Task E.1.3.2 (PNNL), was well designed and described this year. Realizing that there are many Co-Optima projects, it is still unfair to put three in one time slot, as was done this year. The reviewer believed in 2019, there were only two. The experiments had access and used appropriate equipment.

Reviewer 4:
Overall, there was a strong approach in the majority of the projects covered in this presentation. Again, it is difficult on reviewers to make really in-depth comments on the work when so many projects are covered in a single talk. Twenty minutes is barely long enough to include any kind of depth with regard to just one of the

projects, much less for three (or more in some cases). Therefore, if the review quality is lacking this year, this reviewer believed it is due to the project mashups presented (as in 2019) and not due to the online presentation style made necessary by COVID-19.

The reviewer thought it is particularly important to isolate the fuel property impact, and that the approach taken—to vary aromatic content and distillation range while limiting the changes in fuel sensitivity and RON—is a smart way to accomplish that. The reviewer really appreciated all of the synthetic gas reactor work at ORNL; this three-way catalytic converter (TWC) work yet again highlights the importance of bench reactors running realistic exhaust conditions (including water) with a less complex gas profile. It was not clear to this reviewer that the PNNL reactor work includes water in its synthetic gas.

Reviewer 5:
The scope of this work seems focused and somewhat limited. The representation of the fuel variance is interesting, but it is understandable that the effort keeps the variation limited. Are the conclusions drawn from one condition sufficient to represent a "normal" operating envelope? Looking at performance of commercially available TWCs is understandable. Looking at variations expands the degrees of freedom substantially.

Reviewer 6:
This effort focuses on the effects of fuel on engine-out speciation as well as tailpipe emissions. Although the engine-out speciation work is well thought out and inclusive of all the criteria emissions species, the tailpipe emissions results and approach are not as definitive. Those results are highly reliant on the catalyst formulation chosen.

Reviewer 7:
Emissions compliance is arguably the biggest challenge that needs to be addressed for MM/ACI combustion concepts to be production viable. This makes the research undertaken as part of this project perhaps the most critical for the success of MM/ACI combustion. All the sub-projects covered under FT073 are addressing key challenges associated with emissions aftertreatment. As automotive stakeholders have repeatedly stated, it is essential that the fuels for conventional SI combustion and MM/ACI combustion concepts need to be common. MM/ACI combustion concepts have virtually no chance of succeeding if they rely on a different set of fuels. Thus, the PIs are strongly encouraged to use fuels more representative of market fuels. For instance, the fuels used for the investigation of ACI combustion emissions are nominally 87 anti-knock index (AKI), but the RON is lower than the market average (approximately 91.5-92). Additionally, the "High" aromatic case is more representative of the average for the U.S. market. The higher range for aromatics in market fuels tends to be around 35%, instead of 25%.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The evaluation of fuels and the catalyst performance influence were interesting. The investigation utilizing a reactor to characterize species will set expectations, but it will be interesting to see if quantification will be complicated once an engine is used for feed gas.

Reviewer 2:
The Accomplishments of the projects were excellent. For this reviewer, the first one presented was excellent, but harder for this reviewer to evaluate. The findings in the two aftertreatment projects were important, first evaluating the activity of a wide range of HCs that may be used in a Co-Optima fuel and, next, evaluating the activity of nanoparticle versus single-atom catalysts under equivalent conditions was very revealing. However, with only 6minutes per project, further extensions of this work could not be discussed, such as the impact of HCs on the activity of other reactants in the experimental feed in number two.

Reviewer 3:
There was a wealth of information presented from the various thrust areas without a time allotment for extensive background/setup explanation, making it difficult to assess the technical merit. Many of the results presented are already generally accepted as fact. However, these appear to be baseline assessments as the fuel recommendations get passed to the team.

It seems counterintuitive that the particulate mass and particle number (PN) are much lower for the fully stratified (0/100) case relative to the partially stratified (70/30). Even the elemental carbon emissions are higher for the 70/30 case than the 0/100. A major goal of incorporating partial charge premixing is to help lower particulate counts/mass from that of fully stratified operation. The start of injection (SOI) for the late injections is very different for the 70/30 and 0/100 cases. The investigators state that the injection timings were designed to hold CA50 constant for all combustion types, which is a solid strategy. The community looks for a greater host of operating conditions in the SCE testing phase.

Reviewer 4:
Excellent progress has been made over the past year on multiple fronts. The emissions data presented provide valuable insight into the impact of fuel composition on engine-out emissions for various ACI combustion modes. The PI is encouraged to continue this investigation under multiple operating conditions—first steady-state and then transient. Additionally, the investigation of light-down temperatures provides critical information for aftertreatment requirements of MM combustion concepts. It helps underscore the challenge of emissions compliance when operating on current market fuels as it indicates that highly paraffinic fuels will be more difficult to deal with under lean light-down conditions. Low-temperature oxidation using platinum (Pt)/ceric oxide (CeO_2) nanoparticles shows some encouraging results, but more work is needed to aid the development of low-temperature aftertreatment solutions. The PIs are encouraged to include quantifiable performance indicators in future reports in accordance with DOE guidance to reviewers for evaluating projects.

Reviewer 5:
There are strong findings from the past year with regard to defining the fuel chemical properties impact PM mass, whereas the fuel mixing and charge stratification impact the particle size and PN. Also, the tradeoff between NO_x and HCs was identified for ACI modes, with those HC emissions being a strong function of the fuel chemical properties. The ORNL gas bench work demonstrated that HC emissions will be a significant challenge for ACI operating strategies. If the project team cannot make it work under idealized, steady-state synthetic gas conditions, the reviewer struggled to believe that the community will be able to accomplish it on the vehicle.

PNNL work is too early for technical review.

Reviewer 6:
From the standpoint of aftertreatment, the presenter relies heavily on the chosen catalyst to be representative of all catalysts. This is definitely not the case. Unless the catalyst used in this work is an appropriately aged super ultra-low emissions vehicle (SULEV) catalyst, it would not be appropriate to draw strong conclusions from the light-off experiments. Additionally, palladium (Pd), Pd plus rhodium (Rh), and Rh-only formulations react HC differently. All three are used in current aftertreatment systems. Similarly, using the temperature at which 50% of the distillate fuel is recovered in a distillation experiment (T50) as a benchmark for U.S. Environmental Protection Agency (EPA) Tier 3 and California Air Resources Board Low-Emission Vehicle (LEV) III systems is not sufficient. Catalyst systems must work at 99.5% efficiency to achieve these emissions standards. Therefore, the temperature at which 90% of the distillate fuel is recovered in a distillation experiment (T90) performance is also very important. Finally, when comparing the performance of single-atom and nanoparticle catalysts, ensuring that they are aged under the same conditions is important. As a further note, engine calibration can also have an impact on both tailpipe and engine-out emissions and speciation. Finally, the fuel work related to combustion modes is appropriate and provides useful information.

Reviewer 7:
There has clearly been a lot of work done in all of the task areas. Not all seems to have the same value in terms of progress toward the goal. The engine emissions response to fuel chemistry, operating condition, and fuel property is really nice work. The results are not all that surprising, as it seems that a lot of these directional responses were already known. The reviewer would like to have seen more explanation of how these results have expanded our understanding. The light-off/light-down study is valuable, but is an area where it really needs to be linked to engine testing in parallel so that the bench testing can fully replicate what the engine will be doing to the catalyst. The reviewer would have also liked to see more than just HC oxidation but also NO_x reduction, because that is frequently the most difficult pollutant to deal with from a regulatory sense. It will also be useful to consider how the HC/NO_x ratio coming into the catalyst impacts the process, because that is an easy calibration knob. The reviewer questioned how valuable the work in low-temperature catalysis of unburned fuel is; the reviewer would have expected that most of the fuel would be partially combusted, and so again the low-temperature HC/NO_x combined reactivity would be of more significance.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This project does a good job of leveraging the expertise of other Co-Optima teams and industry stakeholders through the Advanced Combustion and Emission Control (ACEC) Low Temperature Aftertreatment working group.

Reviewer 2:
There are strong collaborative efforts, particularly leveraging the Crosscut Lean Exhaust Emissions Reduction Simulations (CLEERS) organization.

Reviewer 3:
The fuels selection is based on Co-Optima identified fuel blendstocks. The efforts, to this point, are fairly distributed. Reactor experiments and fuel characterizations seem to be lumped into a single site effort. The coordination between contributors seems well conducted.

Reviewer 4:
The range of collaborators from various National Laboratories and other organizations means that these projects receive a large degree of comment and discussion during the year.

Reviewer 5:
A significant amount of data was obtained from this fuel work. However, the results would be strengthened if an OEM were a member of this project. There is good inter-laboratory collaboration.

Reviewer 6:
The team does have good internal collaboration. The reviewer thought there needs to be more collaboration with engine teams, though, to ensure that the bench testing is fully relevant to engine operation.

Reviewer 7:
The project team appears to be interacting well with the fuel development teams. However, the counterintuitive PN/PM results from the stratification comparison study call to question the collaboration and communication with the combustion teams. Are they collaborating with Lyle Pickett's FT074 team, who is studying the sooting tendencies of injection events during the intake?

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The future work is appropriate for addressing the selected barriers. The community anxiously awaits the results from different aromatic content and distillation curves in ACI modes.

Reviewer 2:
All the future work identified in the report is very relevant and should be continued. It is critical that the engine experiments should explore a wide range of operating conditions, both steady state and transient. The work on emissions control architectures should include solutions for cold-start emissions as well as particulate emissions.

Reviewer 3:
The future work plans are strong. The reviewer definitely hoped this project is funded at a level to allow for the future work described in the presentation.

Reviewer 4:
The choices for future research appear excellent. For the stoichiometric conditions in projects 2 and 3, it could be useful to examine the impact of dithering the feed around the stoichiometric point, which the reviewer did not recall being discussed. In some systems this can have a large effect. The choice in project 3 to look at bi-metallic nanoparticles is an excellent idea. There are known synergies from studies over the past decades, e.g., Pt/Rh, that could have great interest in today's high-priced environment for platinum group metals (PGMs).

Reviewer 5:
The proposed engine-related work is appropriate and will be informative. The bench reactor and tailpipe emissions results will be less conclusive due to the highly variable nature of catalyst PGM composition and washcoat technology. The engine calibration will also have a significant effect on emissions results.

Reviewer 6:
Moving the work from the surrogates and micro-reactors to MCEs will be interesting. The work to date is focused on one operating condition but attempts to make claims of general applicability. Using more conditions or clarifying specific combustion regimes, if applicable, could be added.

Reviewer 7:
The proposed work is generally good, but does not fully capture this reviewer's comments from previous questions; looking at transient catalysis that is duplicating what we see with engine-mode switching would be highly valuable.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Emissions control will truly be the enabler or death sentence for the Co-Optima fuels and combustion strategies; therefore, this reviewer thought that this presentation represents some of the most important work in the program.

Reviewer 2:
Without the research work covered under FT073, MM and ACI combustion concepts being explored by Co-Optima have no chance of being viable for mass production. Thus, this project is extremely critical for accomplishing the overall DOE objectives.

Reviewer 3:
Emissions compliance may be the biggest challenge for adoption of ACI, so this is a very relevant topic.

Reviewer 4:
To fully evaluate optimized fuels for fuel economy, their emissions control must also be evaluated and optimized, as these projects are providing the data for those optimizations.

Reviewer 5:
The project directly contributes to the DOE goals of reducing vehicle air pollution.

Reviewer 6:
Understanding the fuel composition's influence on catalyst performance is very useful, as is expanding work to include a range of fuels that has a greater or lesser PM production. The combination of fuels with related efficiencies and emissions influences, plus a consideration of the resulting catalyst reactions, is applicable.

Reviewer 7:
Optimizing fuel blends for engine and aftertreatment performance is highly desirable and could help increase fuel economy without sacrificing performance. However, it was noted that a reviewer's statement in the presentation suggested that this work will guide supplier and OEM development activities. That will most likely not be the case. OEMs and their catalyst suppliers develop catalyst systems for currently required Tier 3 fuels. They will not develop a separate catalyst system for another fuel. The onus is on the new fuel to be compatible with the aftertreatment system.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The budget seems fine for the work being done.

Reviewer 2:
The resources used between National Laboratories seems focused and not overly expansive or overreaching.

Reviewer 3:
The reviewer had no issue with resources.

Reviewer 4:
The groups doing each of these sub-projects have the correct equipment for doing the initial evaluations needed and access to other tools to follow up on any surprising results.

Reviewer 5:
The team appears to have appropriate resources for project completion.

Reviewer 6:
The funding is sufficient for the proposed work.

Reviewer 7:
Resources seem sufficient.

Presentation Number: ft074
Presentation Title: Multi-Mode: Gasoline Direct-Injection Sprays
Principal Investigator: Lyle Pickett (Sandia National Laboratories)

Presenter

Lyle Pickett, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

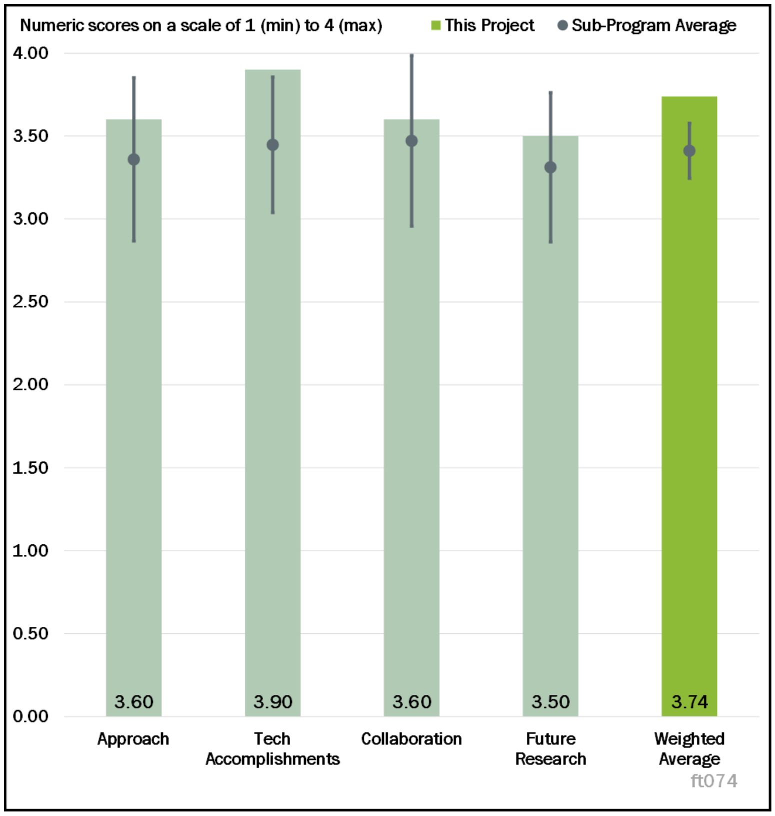

Figure 5-8 - Presentation Number: ft074 Presentation Title: Multi-Mode: Gasoline Direct-Injection Sprays Principal Investigator: Lyle Pickett (Sandia National Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This is outstanding work. Detailed fundamental understanding of in-cylinder spray behavior is being uncovered in extreme detail.

Reviewer 2:

The approach brings to bear the excellent experimental strengths of SNL in spray visualization and measurements. This is supported very well with appropriate CFD modeling of the data.

Reviewer 3:

The combination of experimental and computational aspects makes this an excellent project.

Reviewer 4:

The approach to this project is sound. The work uses spray vessels and high-fidelity simulation to study the spray characteristics of a GDI injector and the impacts of fuel property changes upon those spray characteristics. The work uses a battery of experimental techniques, among several partners, to help develop advanced predictive models for these sprays.

Reviewer 5:

The project approach is tuned to exploit the capabilities of the experimental setup being used. The project explores an aspect of injector performance connecting to mixed-mode work by viewing changes in injector performance at different conditions, including normal SI conditions versus the near top dead center (TDC) injections that could be used in ACI portions of a mixed-mode strategy. The results of this work are applicable to both ACI concepts and conventional SI engines, which will increase the value of the results.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The technical detail and progress of this work are impressive. Substantial insight has been gained into the influence of spray and fuel property characteristics upon soot formation, ignition, and flame propagation. The experiments helped to highlight shortcomings in the Reynolds-averaged Navier-Stokes (RANS) model and led to a substantial improvement in the simulation approaches used to examine these spray conditions, including cavitation and flashboiling.

Reviewer 2:
Very detailed measurements and associated analysis are uncovering new details of the impact of fuel characteristics of spray phenomena.

Reviewer 3:
Measurements and simulations of injector dribble from GDI sprays are a high value output from the last year's effort. A cohesive program to establish some clear results in this area is viewed as valuable.

Reviewer 4:
The new homogenous relaxation model (HRM) that was implemented is a great advancement for CFD that industry users can take advantage of. The team has made great progress to date, given delays due to COVID-19.

Reviewer 5:
Several new and interesting accomplishments have been made. Examples are the growth of the spray plume angle with flash boiling, spray collapse with increasing spray plume angle, wetting of the nozzle face during flash boiling conditions, and modeling work with the HRM of the flash-boiling process. The transparent fuel injector experiments complement the understanding gained with the other tools and modeling. Shortcomings of the RANS model in predicting burning rates have also been noted. The team is congratulated for the good progress and findings.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There are a large number of collaborators in this work, even though only the direct SNL research results were explicitly shown. The ECN work is a major underpinning to this project, and those results are highly leveraged for this project. A large mix of National Laboratories and universities are contributing to this work.

Reviewer 2:
Through Co-Optima, PACE, and the ECN, the collaborations are extensive and contributory.

Reviewer 3:
The team has great partners to collaborate with.

Reviewer 4:
Several appropriate collaborations have been established with other researchers at SNL, ANL, and universities.

Reviewer 5:
There is a good list of collaborations across the different National Laboratories and with outside universities and research groups. Looking at the results discussion, it is less clear how these collaborations supported the results generated within the program.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
It is very important to move toward CI fuels, whether MCCI or ACI combustion systems. Bringing these tools and approaches to the challenges of autoignition—in particular, the autoignition of Co-Optima fuels and fuel components—will be necessary for success.

Reviewer 2:
Through the project team's insightful analysis, it has been able to identify appropriate next steps.

Reviewer 3:
One of the future tasks, "Determine if advanced hardware (high injection pressure GDI) can alter mixtures, dribble, and ignition characteristics," is very interesting and critical since the industry is testing much higher pressure injection for advanced combustion, such as done for gasoline direct injection compression ignition (GDCI) (Delphi) and gasoline compression ignition (GCI) (Aramco).

Reviewer 4:
Going forward, experiments and modeling of real multicomponent fuels will be of use to industry.

Reviewer 5:
From a purely technical standpoint, the proposed future work is solid and represents an opportunity for new knowledge gain that is useful to the engine combustion development community. The impact and connection to the Co-Optima effort as a whole, however, is less clear, and even more so to the Mixed-Mode task. It is important to connect more closely to the Co-Optima Mixed-Mode task objectives. Focus on what this effort can deliver to address a key barrier in mixed-mode concepts, or identify new, key fuel property effects relevant to that area. GDI sprays are relevant, but the alignment between the knowledge from this project and the higher level Mixed-Mode program barriers and objectives could be improved. Moving forward, this reviewer would like to have seen a concentration on using more fuels. Since this is a high-throughput chamber, the project team should evaluate a wider swath of fuels to generate new understanding. Additionally, an increased focus on the impact of specific fuel properties, for example distillation as noted, could be more valuable than focusing on the core Co-Optima fuels. Exploring how big shifts in properties—such as distillation, reactivity, or paraffins, iso-paraffins, olefins, naphthenes, and aromatics (PIONA) classes—would be a valuable addition to the effort.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is essential to achieving DOE goals in a variety of projects. This type of fundamental work is needed.

Reviewer 2:
Understanding the detailed phenomena that occur in sprays is critical to improving engine performance.

Reviewer 3:
The project develops greater understanding of GDI sprays, which supports the overall Co-Optima program goals and ties to DOE targets to increase vehicle efficiency and reduce emissions.

Reviewer 4:
Characterizing injectors is a necessary and critical step to improve engines, thereby meeting DOE objectives.

Reviewer 5:
This project provides the necessary understanding of fuel sprays and mixing processes needed to enable high efficiency engines to reduce petroleum consumption and GHGs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources allocated appear to be consistent with a project of this size and scope.

Reviewer 2:
There is great value for the current funding.

Reviewer 3:
Project resources are sufficient and in proportion to the scale of activity.

Reviewer 4:
Resources are sufficient and not excessive.

Reviewer 5:
The resources are being used extremely effectively to accomplish the stated objectives.

Presentation Number: ft075
Presentation Title: Multi-Mode: Fuel Kinetics
Principal Investigator: Bill Pitz (Lawrence Livermore National Laboratory)

Presenter

Bill Pitz, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 71% of reviewers indicated that the resources were sufficient, 14% of reviewers indicated that the resources were insufficient, 14% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

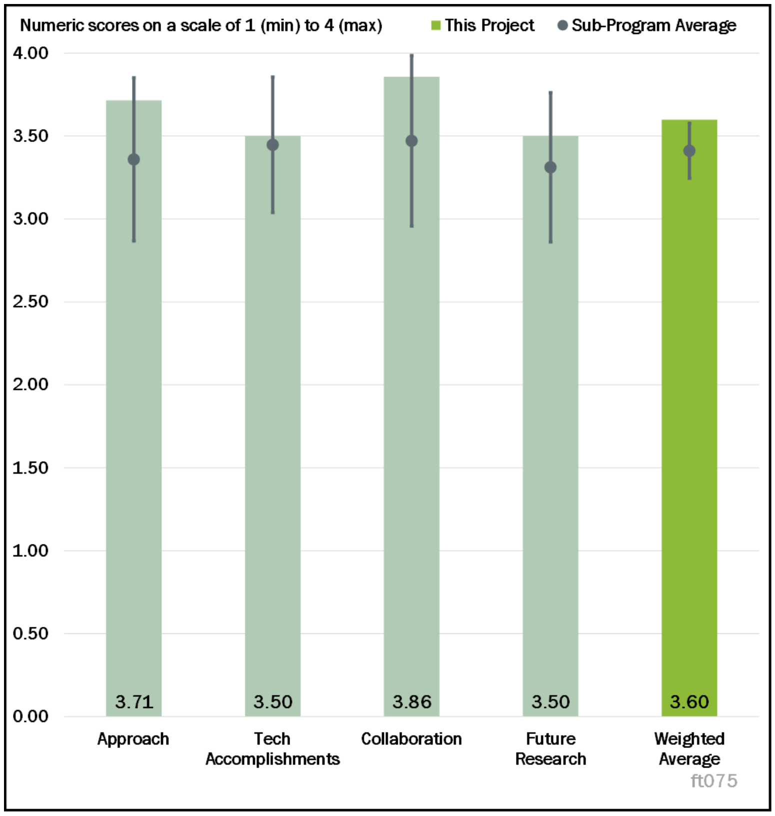

Figure 5-9 - Presentation Number: ft075 Presentation Title: Multi-Mode: Fuel Kinetics Principal Investigator: Bill Pitz (Lawrence Livermore National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project is well integrated with Co-Optima and is intended to fill gaps in kinetic models for a range of combustion modes. It is well focused on barriers and is likely to produce useful results.

Reviewer 2:

Reaction mechanisms and kinetic models are crucial for in-depth understanding of the combustion process as well as pollutant formation. This requires combined efforts of rate calculation, mechanism development, experiments for model validation, and mechanism reduction for real engine simulation. The project is very well designed to cover all areas listed above.

Reviewer 3:

This type of project provides exactly the type of tools the community needs to advance vehicle efficiency and reduce emissions.

Reviewer 4:

Improved chemical kinetic models are essential for enhancing the combustion and emissions modeling capabilities of engine simulation tools. The work presented in this report covers new Co-Optima blending components, the impact of NO_x on autoignition, and polycyclic aromatic hydrocarbon (PAH)/soot formation, all of which address critical needs for improved modeling of various combustion modes, including conventional SI.

Reviewer 5:
The project's overall approach to developing models for soot and PAHs occurring in MM, MCCI, and ACI engine modes is impressive. The project's development of kinetic models that accurately predict the promotion effect of nitric oxide (NO) to ensure accurate simulation of autoignition occurring in MM, ACI (MD/HD), and MCCI engine combustion is also impressive. This program is well thought out.

Reviewer 6:
The approach used in this project has been honed over decades of research into the study of fuel combustion kinetics and has consistently delivered results that have driven the field of combustion research. The further development and refinement of kinetic mechanisms for new fuel molecules, the work on kinetic mechanisms for PAHs (soot precursors), and the influences of NO_x on autoignition kinetics are foundational to the work carried out throughout Co-Optima.

Reviewer 7:
The approach to develop chemical kinetic mechanisms for HPFs just seems like a little bit of cart before the horse. These mechanisms take significant human and capital resources to develop, and it seems like this should be done after more promising candidates are identified in the engine experiments.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Looking at the results in the presentation and thinking back not that many years ago, kinetic models did not have such nice agreement with experimental results. The comparisons between the models and the RCM data are impressive. There is still work that can be done in this space, but just 5 years ago, the difference between models and experimental results was considerably larger. The understanding of chemical kinetics is important in understanding ignition delay, emissions, and, especially, soot formation. This project shows great progress in that understanding.

Reviewer 2:
The model development that has come out of this project is impressive (seven new kinetic models) and led to numerous publications.

Reviewer 3:
This year's presentation notes development of seven new or updated kinetic models for a variety of fuels of interest. It is interesting to see that the results help explain some of the particle emission trends of fuels and blends. It would be interesting to catalogue how industry is using the developments and findings.

Reviewer 4:
The team made very good progress in advancing mechanisms for HPFs and soot formation, as well as the promotion effect of NO_x on autoignition.

Reviewer 5:
The team has made widespread progress on many of the objectives. As with any scenario modeling experimental phenomena, some of the models fit experimental data with various degrees of accuracy. The reviewer had only a couple of areas of concern with the results:

- The n-butanol and iso-butanol ignition delay results on Slide 11 do not appear to capture the correct trend shape. The trend does change from the original model, but caution is advised owing to this perceived trend shape mismatch.

- The allene and propyne models on Slide 13 predict a much narrower distribution than the experiments. The investigators fielded questions on this during the presentation period and cited the intrusive nature of the experimental apparatus as a potential for broadening the experimental distribution. Are there sensitivity studies that can quantify this impact? What are the critical parameters influencing this potential error source (aspect ratio of the probe to some critical length in the experiment?)? Are the investigators certain that this mismatch is created by experimental shortcomings?

Reviewer 6:
Reducing particulate emissions is one of the biggest aftertreatment challenges being tackled by the automotive industry. Thus, it is encouraging to see progress on this front. This work stream needs to be continued further. Improving the ability to model the impact of NO on autoignition will benefit combustion modeling of operating conditions with higher levels of residuals/internal EGR, regardless of combustion mode. Multiple Co-Optima and PACE projects present data on engine combustion simulations which directly and indirectly utilize the kinetic mechanisms developed as part of the current effort. For future presentations, it would be helpful for the audience and reviewers if the report included a slide or two highlighting efforts where the improved kinetic mechanisms have been used. Specifically, it would help to see a comparison of engine combustion simulation with old and improved kinetic mechanisms, as ultimately the motivation for improving kinetic mechanisms is to increase the accuracy of combustion and aftertreatment simulations.

Reviewer 7:
The kinetic sub-models developed for new HPFs consistently perform within the experimental error of fundamental combustion experiments, indicating performance that cannot realistically be substantially improved. The continued integration of new sub-models with the base gasoline model allow the modeling of complex fuel blends and mixtures of Co-Optima HPFs.

One area of potential improvement would be the more rapid transfer of the developed models to the public and stakeholders. The current practice of waiting for key publications to be written, submitted, and reviewed is slowing the utilization of these important tools.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project includes a number of collaborators who are well integrated with the project team’s efforts. This reviewer saw numerous high-impact publications from this collaboration.

Reviewer 2:
The project team collaborates extensively. No deficiencies were identified.

Reviewer 3:
There is outstanding collaboration between National Laboratories, academia (global), and industry.

Reviewer 4:
This is the largest collaborative group this reviewer had seen so far. There are 9 National Laboratories, 10 universities, as well as industry involvement. All of the researchers who are named are considered tops in their field. It is no wonder the results are as good as they are.

Reviewer 5:
Collaboration is strong with five university partners, National Laboratories, international institutions, and interactions with industry.

Reviewer 6:
The collaborations between the LLNL kinetics team and Co-Optima, as well as outside Co-Optima and with the broader community, are so numerous that they are challenging to list on a single page. Specifically, collaborations with engine researchers have driven significant insights into interactions between fuel kinetics

and engine performance/limitations/physics and are an important source of knowledge transfer and sharing throughout Co-Optima.

Reviewer 7:
Collaborations across the team were noted and adequately explained.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The planned objectives and approach for the next years are adequately explained and are focused on the goals and barriers.

Reviewer 2:
The future research is well planned to continue developing and improving kinetic models for gasoline-range and diesel-range fuel candidates, blendstocks for oxygenate blending (BOBs) and their blends, PAH/soot formation, and NO_x effect on combustion. Meanwhile, the reviewer suggested the team should focus more on the phi-sensitivity of fuels, given the potential of lean gasoline combustion.

Reviewer 3:
The future research is very ambitious and very useful. The community eagerly awaits these new/updated models/tools.

Reviewer 4:
The proposed future research is well thought out and should be considered in the future.

Reviewer 5:
As appropriately identified in the report, future efforts should including expanding the range of pressure, equivalence ratio, EGR, and dilution levels over which the kinetic mechanisms are validated. Additionally, the PIs are encouraged to prioritize improving PAH/soot modeling capabilities.

Reviewer 6:
The proposed future research maintains the course of this project and will likely deliver advancements in the key areas listed here (improved BOB kinetics, PAHs, NO_x, and autoignition interactions).

Reviewer 7:
The reviewer called for more model development, which will hopefully become more accurate.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The outputs of this task are foundational to Co-Optima and the DOE VTO engine-research portfolio. The kinetic models developed here continue to shed light on processes occurring inside engines, including modern SI engines, advanced combustion engines, and canonical/academic engine experiments. Further, without the development of accurate kinetic models for novel HPFs, it will be challenging to understand the behavior of these fuels well enough to assess their performance across a range of engines and combustion systems without exhaustive experimental work.

Reviewer 2:
Fundamental fuel combustion research is the foundation of developing advanced clean and high-efficiency engines, and its contribution to support the overall DOE objectives should not be underestimated.

Reviewer 3:
This project is crucial for widespread utilization of Co-Optima results from many groups.

Reviewer 4:
Improved kinetic mechanisms are essential for increasing the accuracy of engine combustion and aftertreatment modeling.

Reviewer 5:
This project will enable engine developers and researchers to use accurate kinetic models to improve MM combustion engines.

Reviewer 6:
This work is relevant to DOE objectives and important for linking the fundamentals to the application.

Reviewer 7:
The research addresses the overall goals of Co-Optima in providing the underpinning science and data for fuel-engine co-development.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources devoted to this project are not sufficient, based on the objectives and promise of this work. Examples of demonstrated need for funding include the University of Connecticut subcontract work, which allows fundamental experimental data to be obtained so that the modeling process can proceed with appropriate validation data.

Reviewer 2:
The project team seems to have enough resources to achieve the stated milestone. The overall budget should be increased to enhance the fundamental research in fuel combustion kinetics.

Reviewer 3:
The resources appear appropriate for the project scope and effort.

Reviewer 4:
Resources appear to be sufficient for the proposed scope of the project.

Reviewer 5:
There is no indication that this group is lacking in resources.

Reviewer 6:
Progress in the tasks has been fine and resources appear adequate. Evaluate this question again in consideration of COVID-19.

Reviewer 7:
The resources seem excessive based on how likely this work is to impact implementation of the Co-Optima fuels or engine combustion strategies. Fundamental work is very important, but the luxury of a wealthy portfolio.

Presentation Number: ft076
Presentation Title: Model-Based Fuel and Engine Optimization
Principal Investigator: Juliane Mueller (Lawrence Berkeley National Laboratory)

Presenter

Juliane Mueller, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

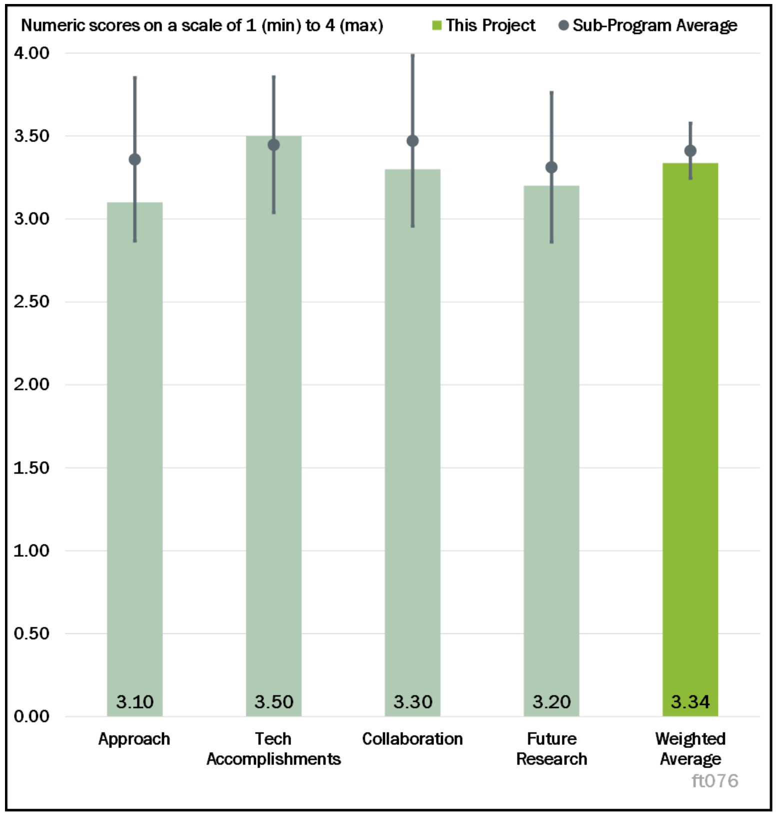

Figure 5-10 - Presentation Number: ft076 Presentation Title: Model-Based Fuel and Engine Optimization Principal Investigator: Juliane Mueller (Lawrence Berkeley National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This approach is really interesting for automating the search for fuels that can match to a combustion approach. That is useful for addressing the technical barriers that prevent ACI adoption within the context of Co-Optima. The project does seem to lack a feedback loop closure though. This reviewer did not see any way to experimentally validate the results of the model search, and there are many ways that kinetic and CFD models can still provide wrong predictions when researchers go away from known regimes.

Reviewer 2:

The approach is unique and combines the existing capabilities of several modeling tools and artificial intelligence (AI) and machine learning (ML) techniques to computationally explore an exhaustive number of possibilities in fuel composition, thus exploring RON and MON ranges that result in expanding the MM load range as well as providing the control parameters like a fuel injection recipe to maximize load. The approach has the potential of being very powerful in narrowing down parameters for experimental validation.

This work has a lot of different thrusts, although the overall theme of speeding up computations and simultaneously improving simulation accuracy is an important one to support the overall Co-Optima program. Some of the pieces of the project seem a bit disjointed to be under a single heading, but the individual projects themselves are using an interesting approach to address important problems. The reinforcement and transfer learning strategies, in particular, are very interesting and will hopefully yield useful results. The approach on this part of the project is unique and was very well explained in the AMR. The reviewer is looking forward to the results next year.

Reviewer 3:
New approaches for characterization and quantification are novel. Identifying a process to select candidate fuels for experimentation is helpful for the sake of analysis, but expanding this technique beyond simple compound fuels increases complexity beyond the ability of the process to efficiently provide insight. Should the process work for more realistic combinations of constituents?

Reviewer 4:
The computational tools developed in this work are very powerful; however, there should be a better way to reconcile the "final" fuel for an architecture and duty cycle. In other words, if a high aromatic fuel is applicable at high load operation and a high olefin fuel is appropriate for robustness, a middle ground needs to be reached depending on the most commonly occurring duty cycle for the engine. The synthesis of that is unclear. One chief piece of information missing is the HOV or the vapor pressure of the fuel. Together with OS, the HOV will govern knocking. So, when a new fuel is concocted, it would be good to get a sense of the HOV as the chemistry models are all gas phase. Finally, many of the fuels have more than 20% aromatic content and some even 40%. Is this violating fuel standards?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The implementation of new approaches to reduce computation time and effort would be extremely helpful in co-optimization of fuel and engine definition. The new approaches shown are very promising.

The accomplishments are on track with their proposed progress; it is good to see that the COVID-19 shutdown has not impeded the work. The PIs have used work-arounds and already available data sets to continue their comparisons and make progress on the method development. The Zero-order Reaction Kinetics (Zero-RK) work is a particularly nice accomplishment as it has been continually improving over the years and still remains an accessible and rapid tool for screening fuels, combustion concepts, and operating conditions. It is good to see the transfer of information from the higher fidelity simulation making an impact on a tool like Zero-RK that could have an impact at an industry level as well. The outcomes of the load range study were very interesting, and the optimization process was quite nice. One open question is the issue of transient operation: load range is not just a range of static loads but also getting from one load to the next. It would be interesting for the PIs to consider how to capture that in an optimization framework or if there is a reduced-order modeling way of considering the effects of fuel composition on transient performance, particularly transient emissions. Finally, the injection strategy optimization with reinforcement and transfer learning is very promising, and there are good initial results.

Reviewer 2:
Technical accomplishments achieved so far seem to be good. The reviewer is very intrigued in the future work on soot formation, especially with greater than 20% aromatic content in the fuel for improving load range. A way to quantify knocking should be established.

Reviewer 3:
While more work remains to realize the full potential of the approach, the results shown thus far for various fuels highlights the power of the approach.

Reviewer 4:
Within the context of the task as it stands, there has been good progress on the model development and application.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The interaction between National Laboratories appears exemplary in this effort. The use of Co-Optima directions is also incorporated well.

Reviewer 2:
Coordination among the laboratory teams is excellent, and there seems to be much progress as a result. There is some coordination with universities, but more is always good. Additionally, the PIs mentioned collaboration plans with software developers like Converge, which is good to see as this will translate these advanced methods to a wider audience. It would be good to see more collaborations with the engine tests and industry, although it seems like that will inherently increase as there is more progress on these tools. Some sort of engine validation exercise on the injection schedule optimization, for example, would be really interesting and maybe not too complicated to accomplish. This would be a great collaboration with a university if the National Laboratory engine research facilities did not have the bandwidth to participate.

Reviewer 3:
The collaboration among LLNL, Lawrence Berkeley National Laboratory (LBNL), NREL, and a couple of universities seems to be working very well.

Reviewer 4:
The collaboration among the modelers looks quite good. This reviewer thought there needs to be a lot more collaboration with the experimental teams, though, to validate the models and make sure that the team is predicting useful results.

Reviewer 5:
The collaboration is sorely missing a fuels company, such as Aramco, Exxon, Shell, or other. Inclusion of a fuels company will help mitigate some of the potentially unrealistic solutions obtained by ML and will help in level-setting the results.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The future research plans in all areas look great. It is also really nice to see a continual transition of updates from Zero-RK to the public domain. This is a major impact of this project on the research and engineering community.

Reviewer 2:
The listed future work on narrowing the RON range, identifying fuel blends, etc., while maximizing ACI load range and minimizing soot are right on the mark. Going forward, the MON and the relationship between RON and MON of the fuel blends should be included in the methodology to address the whole problem. As a byproduct, the fuel injection strategy behavior relative to the optimal results should also be reported.

Reviewer 3:
The proposed work looks fine, though it does not really seem to be working toward some actionable conclusions.

Reviewer 4:
The next steps in process validation are straightforward, though some more practical checkpoints would be useful in maintaining the relevance to the ability to use these techniques in practice.

Reviewer 5:
The soot modeling work is very important and needs to be quantified sooner than later. The HOV effect needs to be quantified in this work, and some parameters for predicting knocking should be introduced.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Faster methods of designing the fuels will be a big boon to Co-Optima.

Reviewer 2:
This project supports DOE objectives on three important fronts. First, it is directly testing the central fuels hypothesis for Co-Optima and making significant advancements toward improving prediction of fuel blends and chemistries. Second, it is translating that learning to the broader community, particularly through tractable models like Zero-RK. Finally, the advanced computing and ML portion of the program is meeting broader DOE goals of advancing supercomputing capabilities and outcomes.

Reviewer 3:
This project aims to identify fuel composition blends that maximize engine ACI load range, thus increasing the potential of mixed-mode combustion engines to reduce petroleum usage and GHGs.

Reviewer 4:
Yes, it supports the Co-Optima effort.

Reviewer 5:
The presentation was delivered well. The explanation of the interaction of the National Laboratory efforts and progress was encouraging to see from an OEM perspective. The reviewer's concern is that the assumptions made, including the homogeneity of the charge, the simplification of the fuel into more discrete compounds and species, and zoned approach to the analysis, will limit the process transfer to more practical use cases.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The team working on this project is a great group of people, and the financial and computational resources seem to be sufficient.

Reviewer 2:
Resources are being used very effectively.

Reviewer 3:
Budgets seem fine for what is being done.

Reviewer 4:
The contribution from each laboratory, and the apparent cooperation with individual efforts, looked to be very functional and key to the progress of the project.

Reviewer 5:
Funding seems to be sufficient for modeling and simulations work.

Presentation Number: ft077
Presentation Title: Heavy-Duty Mixed-Controlled Compression Ignition: Fuel Effects and Ducted Fuel Injection
Principal Investigator: Charles Mueller (Sandia National Laboratories)

Presenter

Charles Mueller, Sandia National Laboratories

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers indicated that the resources were sufficient, 25% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

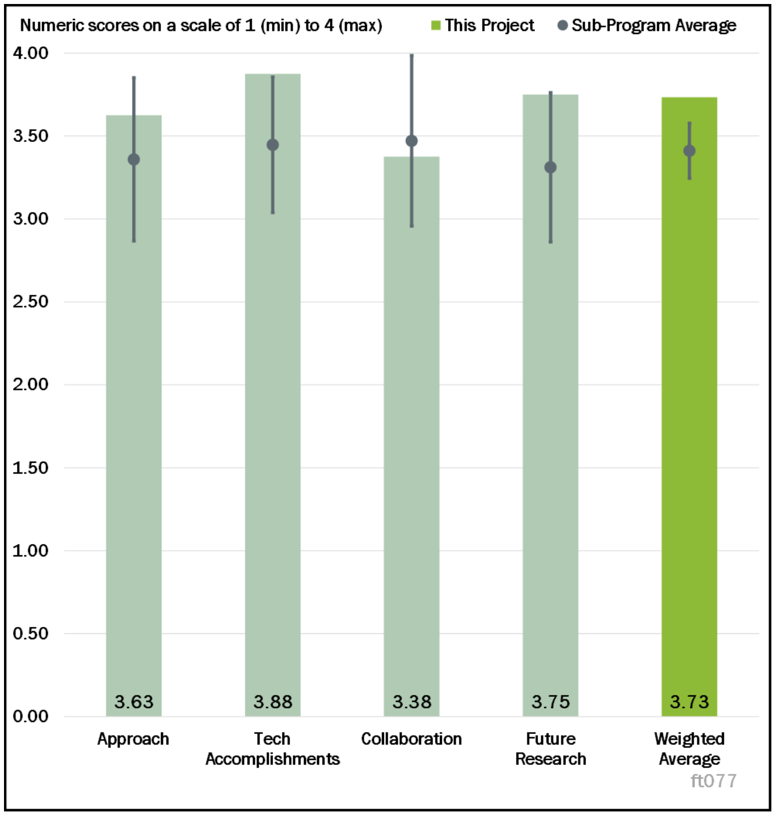

Figure 5-11 - Presentation Number: ft077 Presentation Title: Heavy-Duty Mixed-Controlled Compression Ignition: Fuel Effects and Ducted Fuel Injection Principal Investigator: Charles Mueller (Sandia National Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The potential for DFI is exciting. The work on surrogate fuels and soot is important, interesting, and being addressed in a systematic way.

Reviewer 2:

The team is employing unique experimental capabilities and optical diagnostics together to develop an enhanced understanding of the soot and NOx tradeoff. The approach is working very well.

Reviewer 3:

The approach of this project is effective. The optical engine work is extremely effective in displaying the mechanisms behind why DFI works as a highly effective soot reduction technique. One concern is the very slight reduction in efficiency. With the upcoming GHG and ULNO$_x$ regulations, any emissions reduction approach cannot be accompanied by an efficiency reduction, or the approach will not meet the GHG regulations. It would be helpful to see these constraints included in the approach for the work going forward. It is unclear how the efficiency deficit is going to be addressed.

Reviewer 4:

The optical engine at SNL is used to conduct a systematic, staged investigation of the potential of DFI. The only part missing is CFD modeling to further enhance understanding of the concept.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
There is tremendous progress on the DFI. The insight gained relative to the potential for a relatively simple, low number of component surrogate fuel is good news. And, important questions regarding soot formation have been uncovered.

Reviewer 2:
The team has made excellent progress, given the COVID-19 pandemic.

Reviewer 3:
Outstanding progress has been made in the quantity and quality of experimental work.

Reviewer 4:
This project has made substantial progress toward the goals by moving to a four-hole injector and operating the engine at higher speeds and loads. It is moving beyond proof of concept and more into technology development. Several different engine parameter sweeps were conducted, and the results are promising. However, it is not yet clear how to translate this concept into a practical engine.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There is strong collaboration between the National Laboratories within the Co-Optima program in general, and it appears to be true here as well. The interaction with CRC with the fuels is good. It seems that there is other work on this project besides what was mentioned above. The presenter was not able to disclose the parties involved, but it also represents additional collaboration, which is good.

Reviewer 2:
The team has made excellent progress and is now partnering with ANL for some computational resources in CFD.

Reviewer 3:
Very good collaboration exists between several National Laboratories, Caterpillar, and Ford.

Reviewer 4:
There was mention of collaboration but not much detail was provided with regard to contributions made to the project. It is good that there is finally some simulation capability brought into the project to better help understand some of these fundamental processes. Compared to other Co-Optima projects, the collaboration and coordination in this project is much less pronounced.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future work to further increase the engine load and to increase the number of ducts is necessary and proper.

Reviewer 2:
It appears that the researchers have astutely determined the most important and potentially productive future work for this project. This came through in the discussion regarding raising the load with DFI and whether more than four ducts are possible.

Reviewer 3:
The proposed plan is outstanding, and this reviewer did not see any glaring holes.

Reviewer 4:
Proposed future work listed is to further understand the potential and tie up loose ends, and all the items are right on target. Going forward, the modeling work should catch up with the experimental work.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project supports DOE's goals to maintain high efficiency and reduce toxic air emissions.

Reviewer 2:
The explanation of the relevance on Slide 3 is self-explanatory.

Reviewer 3:
The project is addressing the DOE goals for reducing petroleum use while simultaneously having cleaner combustion.

Reviewer 4:
This project is squarely aimed at overcoming barriers to a wider adoption of conventional diesel combustion in the MD and HD markets, as well portions of the LD market.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources appear to be sufficient to maintain a good level of progress.

Reviewer 2:
There was no indication given that the program is resource limited.

Reviewer 3:
The resources are sufficient to continue the project.

Reviewer 4:
More modeling resources should be allocated to this project.

Presentation Number: ft078
Presentation Title: Heavy-Duty Mixed-Controlled Compression Ignition: Impacts of Fuel Properties on Combustion, Injection Characteristics, and Emissions Controls
Principal Investigator: Martin Wissink (Oak Ridge National Laboratory)

Presenter

Martin Wissink, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

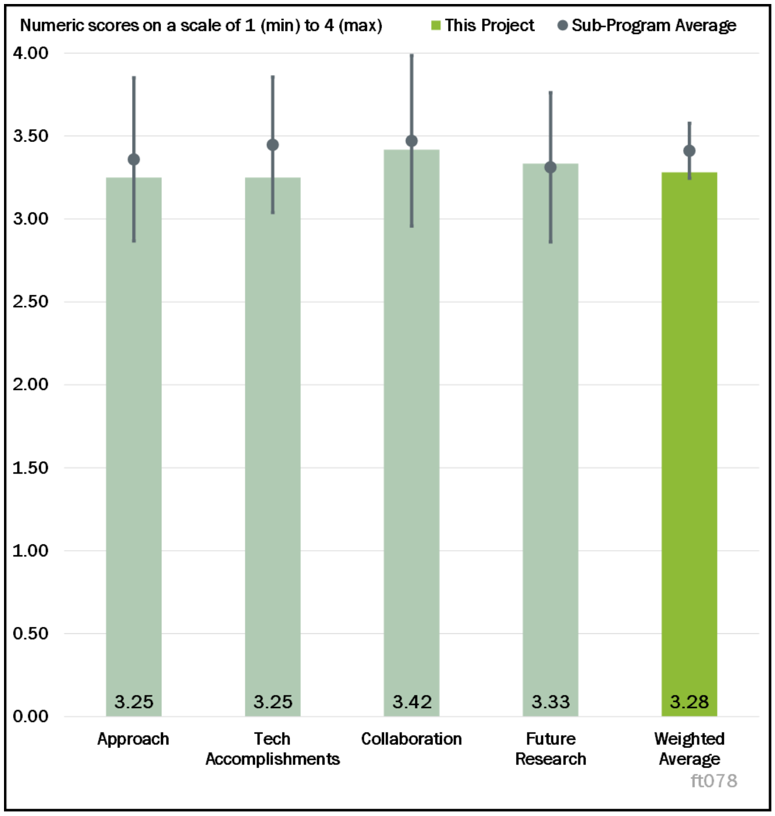

Figure 5-12 - Presentation Number: ft078 Presentation Title: Heavy-Duty Mixed-Controlled Compression Ignition: Impacts of Fuel Properties on Combustion, Injection Characteristics, and Emissions Controls Principal Investigator: Martin Wissink (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The X-ray spray experiments and modeling are excellent examples of how to develop a fundamental understanding of the relationship between fuel properties and emissions. Add to that, the engine-out work that is being done, and this is an outstanding approach to understanding the differences between renewable diesel and diesel fuel with respect to emissions.

Reviewer 2:

Fuel spray and aftertreatment systems are both critical to emission control. Each of them can be a dedicated research project that is worth being funded by DOE. The reviewer did not quite understand why they were combined without providing enough information about how these two tasks are connected. Also, what is the focus of the project? It seems focused on in-cylinder fuel formation and combustion, but most of that work needs to be validated with the aftertreatment system. The reviewer understood that the future engine should be co-developed with the aftertreatment system. So, what could happen if the aftertreatment uses a different catalyst material? The reviewer thought the scope of this project should be better designed. Aftertreatment systems must be one of the key parameters being considered.

Reviewer 3:

The project examines the impacts of fuel properties on MCCI emissions. Biomass blendstocks, which were previously identified, are being examined for their impact on emissions.

Reviewer 4:
As identified in this project, increasing the accuracy of spray models, understanding the impact of fuel composition on emissions formation, and improving combustion during cold-start and low-load operation are all key technical challenges that need to be addressed for the development of more efficient engines with lower emissions. While understanding flow separation inside the injector nozzles is important, developing a better understanding of spray development and fuel/air mixing is critical for improving combustion and reducing emissions. Thus, it is imperative that the efforts of Task G.2.18 are not limited to cavitation. When exploring biofuel blends, it cannot be emphasized enough that the fuels being explored for HD MCCI are compatible with conventional CI engines. If this is not to be the case, then there is virtually no chance of the biofuels being investigated ever being adopted in the market.

Reviewer 5:
While it is very hard to give an in-depth analysis due to the sheer number of projects contained in this presentation, it appears that the projects are well designed and address the relevant technical barriers. (Also - how does the scoring work? Are all projects in the presentation given the same numeric score? What if there is one that is much better or worse than the others? How is this accounted for?) Disappointingly, engine hardware limitations prevent the study of many cold-start strategies.

Reviewer 6:
The multi-faceted approach, combining engine experiments, injection experiments, and modeling, is an appropriate methodology for developing a holistic understanding of the key physics as fuel properties change in MCCI engines. Unfortunately, many tasks are starting and ending at different times, challenging the narrative that this is a cohesive approach.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project made good progress on studying the fuel impact on cold start emissions and light-off, in-cylinder combustion, oxidation catalyst performance, and heating. Some delays due to COVID-19 are understandable.

Reviewer 2:
Many of the technical accomplishments have been hardware related as new systems were brought online for the investigation. Technical accomplishments regarding the diesel oxidation catalyst (DOC) light-off and injector cavitation appear to be on pace.

Reviewer 3:
Each of the tasks included in this project is a significant undertaking, and clearly a lot of work has been done over the past year. However, as per the report, a lot of the FY 2019 effort went into setting up and/or commissioning new test facilities and conducting baseline tests. PIs are encouraged to continue their efforts. Next year’s report with results and observations from the planned testing is expected to be more insightful. The data presented for MD/HD MM light-off/light-down temperatures is particularly interesting. It is encouraging to see the potential to lower both light-off and light-down temperatures. However, it is not clear if the observed trends are due to the change in cetane number (CN) (higher) or the variation in fuel composition (renewable diesel), or a combination of both. The PI is encouraged to develop a better understanding of the underlying mechanism (chemistry or physics, or combination) that leads to lower light-off and light-down temperatures. Finally, all PIs are encouraged to include quantifiable performance indicators in future reports in accordance with DOE guidance to reviewers for evaluating projects.

Reviewer 4:
There are some very impressive accomplishments in this work. The fuel spray work (both X-ray and modeling) is always impressive and yields great results. The reviewer referenced the light-off data when explaining why

the HD OEMs are looking into renewable diesel for the Environmental Protection Agency's (EPA) Cleaner Truck Initiative (CTI).

Reviewer 5:
Technical accomplishments are strong and mostly on track, even in the face of the pandemic.

Reviewer 6:
Many of the tasks reviewed here incorporated new experimental hardware, resulting in a relatively light set of results presented here.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
All sub-projects are engaging relevant stakeholders from the industry, academia, and suppliers.

Reviewer 2:
The collaboration between the National Laboratories is impressive.

Reviewer 3:
Strong collaboration was noted by this reviewer.

Reviewer 4:
The collaboration between project partners appears adequate.

Reviewer 5:
While each subtask made good progress, they seem to be relatively independent. The reviewer suggested highlighting collaborations with industry in "Technical Accomplishments."

Reviewer 6:
The collaboration and coordination varies by task. Tasks E.1.4.1 and G.2.18 appear to have good collaboration and coordination with one another, but this portion of the work has ended. Tasks F.2.4.1, E.2.2.9, and E.2.1/2.8 do not appear to have meaningful collaboration or coordination with one another.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer indicated the proposed research is outstanding. The reviewer suggested, however, that more work be done comparing biodiesel and renewable diesel in both in-cylinder emissions reduction and in the aftertreatment space. This is becoming a larger issue as California and the EPA move toward lower NO_x standards.

Reviewer 2:
The future research plan appears reasonable. The community eagerly awaits the fuel property impacts on emissions.

Reviewer 3:
The proposed future work is reasonable.

Reviewer 4:
The report does a good job of outlining the planned research activities for the next year. The activities identified are in alignment with the stated project objectives. Insufficient information is included in the report to assess the overall plans from the perspective of decision points and recovery options. However, this appears

to be a characteristic of Co-Optima project reports where several large projects are combined under one umbrella project for the purpose of reporting.

Reviewer 5:
The proposed work of Tasks E.2.2.9 and E.2.1.8 both will add value and understanding to MCCI effects on catalyst performance.

Reviewer 6:
The proposed future research should expand to consider various aftertreatment systems and catalyst materials. If only one will be tested, then the reason should be provided.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The research activities outlined in this report are essential for evaluating the potential of MD/HD MCCI emissions compliance and thus support the overall DOE goal to develop more efficient and cleaner engines.

Reviewer 2:
This project allows for a better understanding of how fuel properties affect engine-out and tailpipe emissions. This will benefit both the fuel and transportation industries when designing future vehicles.

Reviewer 3:
These projects are strongly relevant to DOE goals and barriers.

Reviewer 4:
The projects reviewed here continue to have relevance to DOE's transportation research programs, providing insight on phenomena impacting emissions control performance in diesel engines—a major challenge for this technology, the success or failure of which will have significant impacts on energy efficiency in MD and HD transportation.

Reviewer 5:
The project is aligned in support of overall DOE objectives for clean and efficient transportation.

Reviewer 6:
The project is in line with DOE objectives to provide secure and clean mobility.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources appear adequate for the proposed research.

Reviewer 2:
The resources appear adequate for the project objectives.

Reviewer 3:
The funding is sufficient for the proposed work.

Reviewer 4:
It appears that the resources for this project are sufficient.

Reviewer 5:
Resources seem sufficient.

Reviewer 6:
The funding levels are sufficient to support the efforts demanded by the tasks and their proposed future work.

Presentation Number: ft087
Presentation Title: Multimode, Co-Optimized, Light-Duty Vehicle Engine
Principal Investigator: Phil Zoldak (Hyundai-Kia North America)

Presenter

Phil Zoldak, Hyundai-Kia North America

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

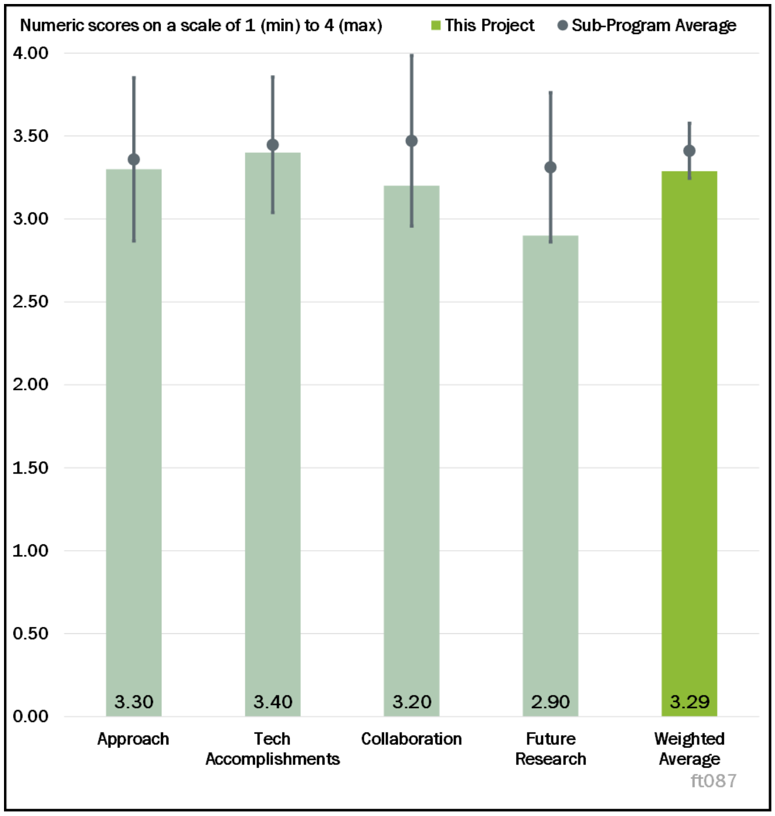

Figure 5-13 - Presentation Number: ft087 Presentation Title: Multimode, Co-Optimized, Light-Duty Vehicle Engine Principal Investigator: Phil Zoldak (Hyundai-Kia North America)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This is a nicely crafted project to transfer technologies from national laboratory projects and the previous Delphi/Hyundai project into a more optimized GCI system by including the fuel properties into the design problem. The approach looks to be addressing all of the key areas of need to bring the system to life.

Reviewer 2:

In general, the approach in this project is excellent. The work is comprehensive, including engine experimental and simulation work. The approach also includes plans to increase the engine load and power output. One suggestion is to become more familiar with previous gasoline LTC work to better understand the dependence of gasoline autoignition upon several engine operational parameters.

Reviewer 3:

The work's goals are explicit. The breakdown of the tasks is reflective of the complexity of the underlying challenges. Carrying the information from other work—fuels surrogate selection, development directions, and demonstrations—is well planned. The focus on a practical demonstrator provides the framework of what must be accomplished to achieve the goals.

Reviewer 4:

The proposed project is planning to address relevant needs described as a part of the 2025 VTO technical goals to improve overall efficiency by increasing LD vehicle fuel economy using advanced SI plus GCI combustion hardware systems in conjunction with novel, co-optimized fuel technologies. The project team is not proposing any examinations of the beneficial impact of lubricating fluid or aftertreatment devices.

Reviewer 5:
The project is to develop a co-optimized fuel and MM SI/GCI engine combustion system that can achieve 15% vehicle fuel economy improvements. The project covers all engine-related development, such as hardware enabling MM combustion, three-dimensional (3-D) CFD, and fuel effect on GCI combustion. However, why is the aftertreatment not part of the scope? Most advanced combustion modes are not commercialized because they have other issues not related to combustion itself. Given the increasingly stringent emission regulations, the story is not complete if a combustion system is not co-optimized with the aftertreatment system.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
There appears to have been a lot of progress this year. The engine performance maps look very impressive, giving promise for satisfying the vehicle fuel economy improvements.

Reviewer 2:
The technical accomplishments are quite impressive. The 1-D and 3-D modeling feeds into the SCE and then into the MCE. The use of variable valve actuation and duration should be a big lever in achieving the goals of this project.

Reviewer 3:
This reviewer observed substantial progress for the first year even with 5 months of delay. The initial design modifications and progress toward a combustion system improvement, including alternative fuel candidates, were significant steps.

Reviewer 4:
The project made good progress and is overall on track.

Reviewer 5:
The reported progress was only discussing preliminary results evaluating hardware selection. The planned selection of novel fuels has been delayed and moved to be conducted during Year 2. Models to examine fuel combustion chemical mechanisms were developed for only four fuels and had not been discussed as a part of the presentation.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The use of the collaborators shows in the progress that was made. Combustion simulation and fuels details—along with the design effort, turbo selection, and pull-ahead controls work—is well coordinated and seemingly well executed.

Reviewer 2:
The work from the partners looks very nice; it does not look like some of their work has yet reached engine testing, so it will be good to see more of that in the coming year. The work from the partners does look significant in terms of satisfying the final project goals, so the reviewer suspected the collaborations are working pretty well.

Reviewer 3:
The team of researchers is aligned as the subject project contributions include representatives of an OEM (Hyundai), a turbocharger supplier (Garrett-Motion), a petroleum fuel company (Philips 66), a National Laboratory (ANL), and academia (Michigan Technological University). It would be advantageous to add experts from NREL to expand knowledge and key contributions related to alternative fuels technologies and combustion models.

Reviewer 4:
This appears to be a good team consisting of an OEM, a university, and a fuel company. The coordination and collaboration appear to also be good among team members. This project could likely benefit from some collaboration with a National Laboratory that has experience in GCI, or possibly an injector company that is experienced in GCI.

Reviewer 5:
There is limited collaboration with National Laboratories and other OEMs, which is understandable because this project is cost shared by Hyundai.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The work plan as presented is well crafted to move the project toward a satisfactory completion. The reviewer would like to have seen more details into the aftertreatment development plans as that has been a big challenge for previous GCI projects. The low-load operation improvement plans look good, and the reviewer hoped that the project team will bring in the fuel co-optimization work too.

Reviewer 2:
The stated future work involving the exploration of intake air heating, spark assist, and possible mode switching is reasonable. However, it might be useful to explore boost sweeps as well, since that will directly influence the ignition properties for most gasoline fuels.

Reviewer 3:
The future research plan does not include examining the potential beneficial impact of novel, low-viscosity lubricant technologies nor assessing the impact of advanced emissions control systems. No specific plans are proposed to examine potential occurrence of the pre-ignition (also called mega knock or LSPI) phenomena taking place at low loads and low speed and strongly dependent on the quality of combusted fuels as well as specific composition of the lubricating oils.

Reviewer 4:
Future research was not mentioned; future steps for the program were.

Reviewer 5:
Very limited information is provided. The reviewer hoped aftertreatment can be part of the project and hopefully vehicle demonstration, instead of vehicle simulation.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
If the final vehicle can meet standards for the super ultra-low emissions vehicle with 0.030 grams/mile combined non-methane organic gases and NO_x (SULEV30) emissions and achieve a 15% reduction in fuel consumption, that offers a big gain in LD fuel consumption within the U.S. market.

Reviewer 2:
This project supports the DOE overall objectives to improve engine efficiency and reduce criteria emissions.

Reviewer 3:
This project is an application of developments that will lead to the VTO 2025 goals. The specificity of this project directly led by and primarily benefitting a single OEM in the long run seems somewhat limited. The evaluation of processes and approaches leveraged from other programs should increase so that the larger

community can benefit from the experience. The project plan and approach are sound and logical. The project contributors are well suited for their identified tasks. It will be great to see the progress made next year.

Reviewer 4:
The project is aligned in support of overall DOE objectives for clean and efficient transportation.

Reviewer 5:
The project is planning to address the DOE objective of up to 15% fuel economy improvements in LD vehicles, but the project has relatively restricted focus by planned examination limited to hardware and fuels, and not including emissions control devices and lubricating fluids.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The proposed budget should be able to deliver planned project goals in a timely fashion.

Reviewer 2:
Budget and spend rates look about right for the project scope.

Reviewer 3:
The resources appear to be sufficient to achieve the target goals in the expected timeline.

Reviewer 4:
The project plan and approach are sound and logical. The project contributors are well suited for their identified tasks. It will be great to see the progress made next year.

Reviewer 5:
The resources appear adequate for proposed research.

Presentation Number: ft088
Presentation Title: Fuel Property Experimental Kinetics
Principal Investigator: Gina Fioroni (National Renewable Energy Laboratory)

Presenter

Gina Fioroni, National Renewable Energy Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers indicated that the resources were sufficient, 20% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

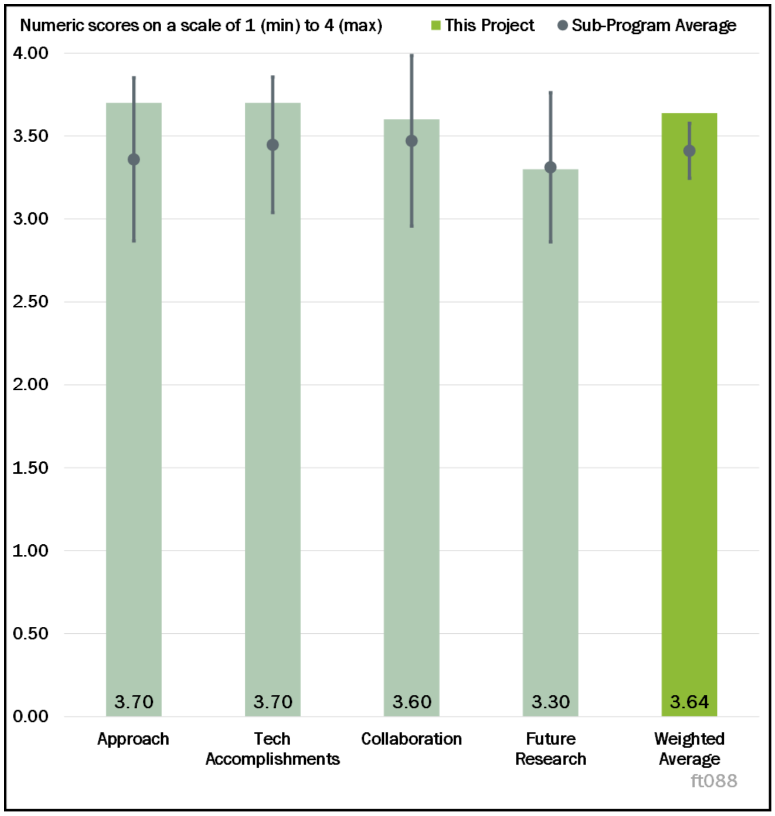

Figure 5-14 - Presentation Number: ft088 Presentation Title: Fuel Property Experimental Kinetics Principal Investigator: Gina Fioroni (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach to better understanding the kinetics of autoignition, particularly the influence of mixing (phi-sensitivity) on autoignition, is critically important. Autoignition is the key to enabling any type of LTC and the key to understanding how to leverage fuel properties for advanced engines. This project uses a variety of tools, both experimental and simulation, to study these autoignition and fuel kinetics properties.

Reviewer 2:

This is excellent work. The research is identifying the fundamental kinetic mechanisms that lead to OS and ultimately could provide synergistic blending relative to the fuels' autoignition characteristics. It has the potential to ultimately facilitate fuel blending with lower carbon footprint blending agents that will allow advanced engine combustion configurations while maintaining compatibility with legacy fleets. It is still in its fundamental phase, but it is exciting.

Reviewer 3:

The team has a nice, systematic approach to characterize the kinetics.

Reviewer 4:

The approach brings to bear the chemical kinetics expertise of the various National Laboratories to identify blendstocks to gasoline to attain certain desirable fuel properties. World-class experimental measurements of the kinetic behavior are measured in the flow reactor, advanced fuel ignition delay analyzer (AFIDA), and the RCM.

Reviewer 5:
A good range and variety of tools are being applied to understand fundamental fuel behavior. It would be helpful to see more clarity and specificity on technical barriers being addressed. Currently, the program is targeted toward resolving a very high-level lack of fundamental chemistry knowledge. Building this out to clarify specific targets and gaps, which are critical to other development programs, would be a useful further step.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Progress toward accomplishing the goals has been excellent. It is impressive to see how much has been learned about the dependence of phi-sensitivity upon different HC component structures and the ability to predict the performance of a fuel component based upon this information. The fuel phi-sensitivity index that has been developed should be a very useful tool going forward.

Reviewer 2:
The identification of the details of the fuel structure and its impact on the autoignition chemistry is outstanding new knowledge.

Reviewer 3:
It is great news that the higher pressure reactor design is done and can possibly be used soon.

Reviewer 4:
Excellent progress has been made in experimental fuel kinetics, with the autoignition characteristics of several blends tested and correlated. Several kinetic mechanisms have been improved. Measurements of phi-sensitivity have been made using the AFIDA apparatus.

Reviewer 5:
The work on flow reactors and understanding the fundamentals of chemical reaction shifts is very important and valuable work. Fundamental chemistry effects are a crucial part of the fuel-engine interactions, and this project is delivering insightful results toward understanding these factors. This effort should be an expanded focus of the Co-Optima program. There is solid progress on the RCM studies at ANL, though these appear to have been hampered by a laboratory move that delayed results. However, clarifying further, and improving the tie to, the overall project objective would be a useful exercise to ensure understanding of the project's connection to the larger effort.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Excellent collaboration exists between NREL, ANL, PNNL, and several universities.

Reviewer 2:
There is excellent collaboration with the partner National Laboratories.

Reviewer 3:
This project shows a high degree of coordination and collaboration among the partners. The AFIDA and RCM work complement each other well.

Reviewer 4:
As with the other Co-Optima projects this reviewer critiqued, the collaboration is very strong and productive.

Reviewer 5:
Recognizing that the project itself is inherently cooperative, requiring collaboration with a range of different laboratories, the connections between the National Laboratories involved in this specific effort is not obvious. Moving forward, the connection between different subproject goals, focus, and activities should be enhanced and highlighted.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The researchers appear to have identified the fundamental aspects of the problem that needs further investigation and have planned out a reasonable approach to obtaining that information.

Reviewer 2:
Proposed future work looks to continue and build upon the work thus far. There needs to be additional clarity on potential breakpoints and go/no-go decisions to mitigate risk of program failure. Note that kinetic mechanism development is focused on prototypical ACI fuels, and therefore project timing is dependent on other programs highlighting properties for a prototypical ACI fuel and down-selecting potential candidates. Given this, a decision point on this effort would be appropriate.

Reviewer 3:
More chemical kinetic investigations of stoichiometric gasoline mixtures with EGR should be carried out as applicable to the LD industry.

Reviewer 4:
The proposed future work looks to be appropriate and an extension of previous success to accomplish the overall goals. The move toward more diesel-like fuels is probably needed, although it should also be viewed with an eye toward how it fits into the overall goal of improving efficiency and reducing GHG footprint as well. Most proposed e-fuel solutions tend to center around simpler HCs rather than long-chain ones. Long-chain HCs certainly tend to mimic diesel fuel more accurately than shorter ones, in general. But, they also tend to come at a higher cost of yield and expense (both energy in processing and dollars). It would be good to keep these multi-variable effects in mind.

Reviewer 5:
The reviewer was a bit concerned about the fit of the work in the overall Co-Optima program since it is very fundamental work and the experimental studies on mixed-mode ACI will likely be conducted without much input from this work. How much impact has the project team considered on engine testing and fuel choices to date? What about the future?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is very relevant to DOE’s goals and objectives. Understanding the fuel kinetics and phi-sensitivity of these fuel components is mission critical to fundamentally improving engine combustion for improved efficiency and GHG reduction.

Reviewer 2:
This work could play a critical role in improving a fuel’s performance for enhanced engine efficiency and at the same time be on the glide path for reducing the carbon footprint of the fuel.

Reviewer 3:
The work does support the DOE goals of increased engine efficiency by laying the fundamentals for new fuels.

Reviewer 4:
This work is aimed at understanding fuel property behavior and fuel blends to enable high engine efficiency.

Reviewer 5:
The project's focus is on fundamental understanding of fuel properties, which is of clear value to the research community. How this understanding directly connects with the higher level Co-Optima research goals needs to be highlighted. What are the ultimate deliverables, and how do they fit within the larger Co-Optima narrative and contribute to overall Co-Optima program outcomes?

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
It seems that the funding is sufficient.

Reviewer 2:
Project resources seem sufficient for the scope and scale of the effort.

Reviewer 3:
Resources are sufficient and not excessive.

Reviewer 4:
Resources are sufficient to accomplish the stated goals.

Reviewer 5:
This type of fundamental science work to understanding autoignition and fuel properties would benefit from some additional resources to move progress along more quickly. Improved experimental equipment and facilities and improved simulation capability would be of benefit to this work.

Presentation Number: ft089
Presentation Title: Heavy-Duty Advanced Compression Ignition
Principal Investigator: John Dec (Sandia National Laboratories)

Presenter

John Dec, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

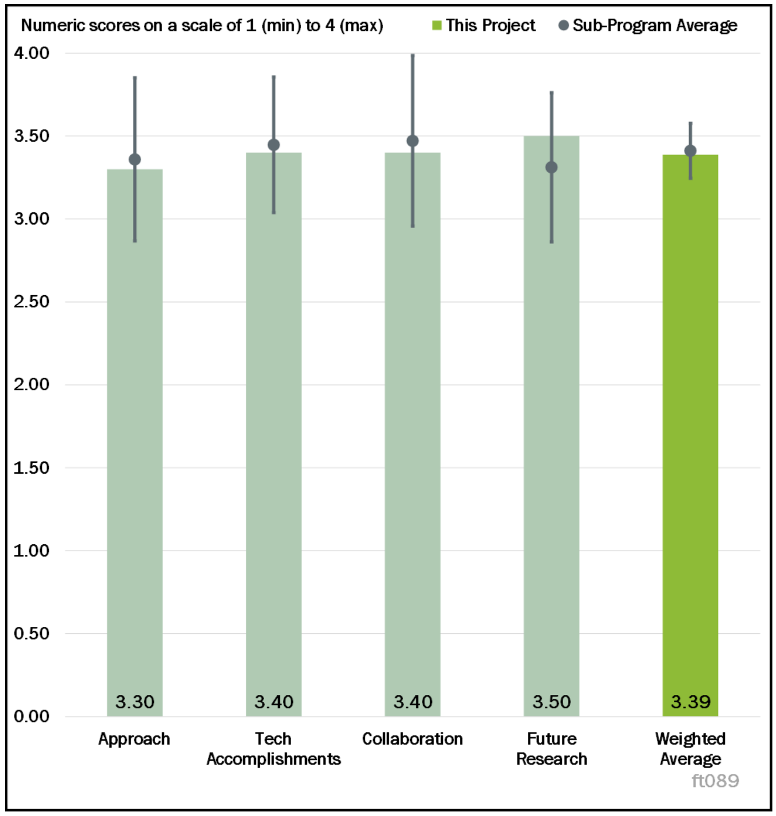

Figure 5-15 - Presentation Number: ft089 Presentation Title: Heavy-Duty Advanced Compression Ignition Principal Investigator: John Dec (Sandia National Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The current approach of including three engine projects and making conclusive findings with integrated results is excellent! Well-integrated CFD for all three platforms can make the analysis stronger in this project. The existing approach will address most of the needs, but to judge “improving combustion-phasing control,” transient and cycle-by-cycle engine data should be studied.

Reviewer 2:

The reviewer appreciated the growth of this project to include multiple combustion approaches. All of the ACI approaches have significant challenges remaining to be addressed before they are feasible for production implementation in HD engines; pursuing multiple pathways at the same time should allow for cross-knowledge and a faster path to technology development. The reviewer was also glad to see that modeling support tasks have been brought in as well; good modeling tools are critical to development of the ACI systems.

Reviewer 3:

The approach taken to document autoignition metrics was excellent. The impingement study lacked the same effort in metrics and variation. The wide variation in the tasks makes the cohesion of conclusions unclear. How do these efforts complement each other?

Reviewer 4:

The overall goal of this effort is to understand fuel properties that can improve engine performance and emissions. Three different engine projects were presented for this review. Individually, each effort is well designed, planned, and executed toward the goal of understanding fuel property impacts on advanced combustion strategies. A comment from this reviewer is that the various combustion strategies are more similar than different, and it is misleading to use different acronyms for them (i.e., they are different shades of gray, and rather than give them all different names it would be more beneficial to describe them and give them names that are indicative of where on the spectrum of "gray" that they fall). There seems to be a penchant for new acronyms and names; taking a step back and standardizing nomenclature would be beneficial, at least in the opinion of this reviewer.

Reviewer 5:
The idea of exploring the potential for changes in fuel composition and characteristics to improve MD and HD engines, which are primarily diesel powered, is good. It seemed to the reviewer that there is tremendous overlap between parts of this project and project ACE157 with the same PI. It would be helpful to articulate the synergies and distinctions. Is it hoped to develop a new fuel that will not need to be augmented like low-temperature gasoline combustion (LTGC)-additive-mixing fuel injection (AMFI)?

It seemed to the reviewer that for any changes in fuel characteristics to be acceptable for this market, they will have to be capable of maintaining high efficiency at maximum load, which is an important operating condition for these engines, especially in the HD sector. To that end, this reviewer thought engine projects 1 and 2 will be extremely challenging when using gasoline-like fuels, an expression that was used during the presentation. Achieving high load with LTGC and GCI will be extremely difficult without something like AMFI. Engine project 3, which the reviewer interpreted to be more of an MM operation, makes more sense in terms of a single fuel.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
While some slight delays were encountered due to the COVID-19 pandemic, the efforts have made very good progress and their delays are understandable given the pandemic.

Reviewer 2:
Despite the unavoidable effects by COVID-19, the project has made very good progress and is on track. The project results show strong accomplishments on Objectives 1 and 2 from the work done at SNL, which is very interesting.

Reviewer 3:
There was some good technical progress on all the tasks, including the new ones. With so many tasks to cover, it is difficult to tell exactly how much progress has been made toward the goal of this chunk of Co-Optima.

Reviewer 4:
Significant progress was made in several areas. The individual contributors provided very detailed explanations of their results, both expected and unexpected. Identifying the limitations of using OI as a metric was challenged and explanations given. The evaluations of fuel blends led to useful conclusions. Some tasks are too new to draw conclusions or gain insight.

Reviewer 5:
Two of the projects are just starting so it is too early to expect significant results. The results for the LTGC are interesting but seem to be for relatively light loads, phi = 0.36. The custom blend (CB) #1 fuel looks very interesting.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The teams all have good collaborations among the Co-Optima areas. The reviewer encouraged the three engine teams to communicate about their findings to see where there may be cross-knowledge and how their findings might support mode switching and other factors that could be important for commercial technology transfer.

Reviewer 2:
Collaboration looks very good as with all Co-Optima projects. The reviewer was curious about the extent to which the industry partners, Cummins and Caterpillar, are engaged in discussions on the technical work plan, in addition to offering equipment support.

Reviewer 3:
The project is well coordinated among the four groups at three National Laboratories. The reviewer understood that a good portion of the activities are supposed to occur in the future. Strong integration of CFD results with engine experimental studies for all the studied experimental platforms is very important for in-cycle combustion and emission analysis to provide conclusive outcomes from this project.

Reviewer 4:
The efforts were spread between many laboratories, and each performed their tasks well. The overlapping focus from contributors can sometimes slow progress, but this work seems to escape that.

Reviewer 5:
While the individual efforts are coordinated with Co-Optima and engage with universities and OEMs as appropriate, the most significant concern of this reviewer is that the three efforts reviewed in this presentation appear to be wholly separate from one another with virtually no coordination. The overall Co-Optima goal is to co-optimize engine and fuels, but there is no attempt to coordinate the results and efforts of these three projects with one another, and thus it is not at all evident how these efforts actually lead to Co-Optima achieving its goals. A coherent plan for ultimately determining “best” (or even “better”) combinations of fuel, hardware, and combustion strategy is warranted. This could, for example, be approached as determining what fuel properties allow for the most flexibility in hardware, or that allow for the broadest range of engine operation with a given strategy. Alternatively, it could be approached as determining what combustion strategy or strategies are most tolerant to variations in fuel properties. Perhaps data to do so have been collected, and this meta-analysis simply needs to be done.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The future work plans look good and should continue to push the tasks toward their targets.

Reviewer 2:
Individually, the planned next steps for all of these efforts are logical and appropriate.

Reviewer 3:
Given the current project objectives, the work planned is logically laid out.

Reviewer 4:
The planned activities are logical next steps. It is important that engine combustion and control analysis will also include cycle-by-cycle engine transient data.

Reviewer 5:
The future work is focused on the specific tasks, and this reviewer would like to have seen how this array of tasks comes back to a cohesive collection to allow directions and decisions to be made in co-optimization efforts. The tasks seem too specific for such a large variation of tasks.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
These tasks support the need to improve MD/HD fuel economy and are areas of interest to the HD community.

Reviewer 2:
The fundamental tasks and investigations that comprise this single project will aid various efforts in the fuel and IC engine areas. The characterization of new fuel-ignition metrics and spray formation and evolution is in step with taking more steps in ACI and the emissions and fuel economy benefits that are shown in this project. The cascading of techniques and discoveries made in this project need to be vetted as this reviewer is concerned that the evaluations are specific to the individual efforts being undertaken.

Reviewer 3:
The idea of exploring the potential for changes in fuel composition/characteristics to improve MD and HD engines, which are primarily diesel powered, is good. It is relevant to DOE objectives.

Reviewer 4:
Yes, this project directly supports the DOE Strategic Objective to “Deliver the scientific discoveries and major scientific tools that transform our understanding of nature and strengthen the connection between advances in fundamental science and technology innovation.” The outcomes of the project provide stepping stones toward fuel-efficient, clean IC engines.

Reviewer 5:
To the extent that these efforts are aiming to improve engines and fuels, these efforts are aligned with DOE’s objectives. However, as noted above, more effort is needed to ensure that these efforts align with Co-Optima’s goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Budgets look fine for the work scopes.

Reviewer 2:
The amount of work that is described in these efforts is remarkable. The task breakdown, the analysis execution, and the presentation of results using so many different contributors are well done.

Reviewer 3:
The resources are sufficient for achieving project success in a timely fashion.

Reviewer 4:
It appears that the support is sufficient.

Reviewer 5:
The team has access to required resources to conduct this project.

Acronyms and Abbreviations

AFC	Alternative Fuel Corridor
0-D	Zero-dimensional
100LL	100 low lead
3-D	Three-dimensional
ACEC	Advanced Combustion and Emissions Control
ACI	Advanced compression ignition
AEC	Advanced Engine Combustion
AFIDA	Advanced fuel ignition delay analyzer
AI	Artificial intelligence
AKI	Anti-knock index
AMFI	Additive-mixing fuel injection
AMR	Annual Merit Review
ANL	Argonne National Laboratory
BETO	Bioenergy Technologies Office
BOB	Blendstocks for oxygenate blending
Ca	Calcium
CA50	Crank angle at 50% mass fraction burned
CB	Custom blend
CeO_2	Cerium oxide (ceria)
CFD	Computational fluid dynamics
CFR	Cooperative fuel research
CI	Compression ignition
CN	Cetane number
CO	Carbon monoxide
CO_2	Carbon dioxide
CRC	Coordinating Research Council
CTI	Cleaner Truck Initiative
DFI	Ducted fuel injection

DOC	Diesel oxidation catalyst
DOE	U.S. Department of Energy
E15	Gasoline blended with 10.5%-15% ethanol
ECN	Engine Combustion Network
EGR	Exhaust gas recirculation
EPA	U.S. Environmental Protection Agency
FY	Fiscal year
GCI	Gasoline compression ignition
GDCI	Gasoline direct injection compression ignition
GDI	Gasoline direct injection
GHG	Greenhouse gas
GM	General Motors
HC	Hydrocarbon
HCCI	Homogeneous charge compression ignition
HD	Heavy-duty
HOV	Heat of vaporization
HPF	High-performance fuels
HRM	Homogeneous relaxation model
iHOV	Instantaneous heat of vaporization
K	Empirical factor (or constant)
L	Liter
LBNL	Lawrence Berkeley National Laboratory
LD	Light-duty
LEV	Low-emission vehicle
LLNL	Lawrence Livermore National Laboratory
LSPI	Low-speed pre-ignition
LTC	Low-temperature combustion
LTGC	Low-temperature gasoline combustion

LW	Livengood-Wu
MCCI	Mixing-controlled compression ignition
MCE	Multi-cylinder engine
MD	Medium-duty
ML	Machine learning
MM	Multi-mode
MON	Motor octane number
MOU	Memorandum of understanding
NMR	Nuclear magnetic resonance
NO	Nitric oxide
NO_x	Oxides of nitrogen
NREL	National Renewable Energy Laboratory
NTC	Negative-temperature coefficient
OEM	Original equipment manufacturer
OI	Octane index
OS	Octane sensitivity
PACE	Partnership for Advanced Combustion Engines
PAH	Polycyclic aromatic hydrocarbon
Pd	Palladium
PFS	Partial fuel stratification
PGM	Platinum group metals
PI	Principal investigator
PIONA	Paraffins, iso-paraffins, olefins, naphthenes, and aromatics
PM	Particulate matter
PMI	Particulate matter index
PN	Particle number
PNNL	Pacific Northwest National Laboratory
PPCI	Partially pre-mixed compression ignition

Pt	Platinum
P-T	Pressure-temperature
Q&A	Question and answer
R&D	Research and development
RANS	Reynolds-averaged Navier-Stokes
RCM	Rapid compression machine
Rh	Rhodium
RON	Research octane number
SACI	Spark-assisted compression ignition
SCE	Single-cylinder engine
SCR	Selective catalytic reduction
SI	Spark ignition
SNL	Sandia National Laboratories
SOI	Start of injection
SON	Supercharged octane number
SPI	Stochastic pre-ignition
SULEV	Super ultra-low emission vehicle
$SULEV_{30}$	Super ultra-low emissions vehicle with 0.030 grams/mile combined non-methane organic gases and NO_x
T50	Temperature at which 50% of the distillate fuel is recovered in a distillation experiment
T90	Temperature at which 90% of the distillate fuel is recovered in a distillation experiment
TDC	Top dead center
TWC	Three-way catalyst
U.S.	United States
$ULNO_x$	Ultra-low NO_x
USCAR	United States Council for Automotive Research
VTO	Vehicle Technologies Office
WTW	Well-to-wheels

Y	Yield-sooting index
Zero-RK	Zero-order Reaction Kinetics

6. Materials Technologies

The Vehicle Technologies Office (VTO) has a comprehensive portfolio of early-stage research to enable industry to accelerate the development and widespread use of a variety of promising sustainable transportation technologies. The research pathways focus on fuel diversification, vehicle efficiency, energy storage, and mobility energy productivity that can improve the overall energy efficiency and efficacy of the transportation or mobility system. VTO leverages the unique capabilities and world-class expertise of the National Laboratory system to develop innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures; and energy efficient mobility systems. VTO is uniquely positioned to address early-stage challenges due to strategic public-private research partnerships with industry (e.g., U.S. DRIVE, 21st Century Truck Partnership) that leverage relevant expertise. These partnerships prevent duplication of effort, focus DOE research on critical R&D barriers, and accelerate progress. VTO focuses on research that industry does not have the technical capability to undertake on its own, usually due to a high degree of scientific or technical uncertainty, or that is too far from market realization to merit industry resources.

The Materials Technology (MAT) subprogram supports early-stage R&D of technologies for vehicle lightweighting and improved propulsion (powertrain) efficiency applicable to light- and heavy-duty vehicles. The MAT research portfolio supports the VTO goals of affordable transportation and energy security. Reducing the weight of a conventional passenger car by 10% results in a 6%–8% improvement in fuel economy, and similar benefits are achieved for battery electric and heavy-duty vehicles. Research focuses on activities that have a high degree of scientific or technical uncertainty or that are too far from market realization to merit sufficient industry emphasis and resources. The MAT subprogram accomplishes its technical objectives through research programs with academia, National Laboratories, and industry.

Propulsion Materials Technology supports research at National Laboratories to develop higher performance materials that can withstand increasingly extreme environments and address the future properties of a variety of relevant, high-efficiency powertrain types, sizes, fueling concepts, and combustion modes. The activity continues to apply advanced characterization and multi-scale computational materials methods, including high performance computing (HPC), to accelerate discovery and early-stage development of cutting-edge structural and high temperature materials for more efficient powertrains.

Lightweight Materials Technology supports National Laboratory research in advanced high-strength steels, aluminum (Al) alloys, magnesium (Mg) alloys, carbon fiber composites, and multi-material systems with potential performance and manufacturability characteristics that greatly exceed today's technologies. This includes projects addressing materials and manufacturing challenges spanning from atomic structure to assembly, with an emphasis on establishing and validating predictive modeling tools for materials applicable to light- and heavy-duty vehicles.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0)*. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 6-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat118	Functionally Designed Ultra-Lightweight Carbon-Fiber Reinforced Thermoplastic Composites Door Assembly	Srikanth Pilla (Clemson University)	6-8	3.25	3.00	3.50	3.25	**3.16**
mat122	Close-Proximity Electromagnetic Carbonization (CPEC)	Felix Paulauskas (ORNL)	6-12	3.00	2.75	3.13	3.00	**2.89**
mat124	Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber for Lightweight Vehicles	Xiadong Li (University of Virginia)	6-16	3.67	3.67	3.50	3.50	**3.63**
mat125	Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber	Jeramie Adams (Western Research Institute)	6-19	3.33	3.00	3.50	3.17	**3.17**
mat126	Room-Temperature Stamping of High-Strength Aluminum Alloys	Aashish Rohatgi (PNNL)	6-22	3.00	2.75	3.25	3.00	**2.91**
mat127	U.S. Automotive Materials Partnership Low-Cost Magnesium Sheet Component Development and Demonstration Project	Randy Gerken (Fiat Chrysler Automotive)	6-24	3.38	3.38	3.63	2.75	**3.33**
mat136	High-Performance Computing and High-Throughput Characterizations toward Interfaces-by-Design for Dissimilar Materials Joining	Xin Sun (ORNL)	6-28	3.33	3.17	3.33	3.17	**3.23**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat137	Adhesive Bonding of Carbon-Reinforced Plastic to Advanced High-Strength Steel	Zhili Feng (ORNL)	6-31	2.63	2.88	3.13	2.75	**2.83**
mat138	Solid-State Joining of Magnesium Sheet to High-Strength Steel	Piyush Upadhyay (PNNL)	6-35	3.38	3.25	3.25	3.25	**3.28**
mat139	Mechanical Joining of Thermoplastic Carbon-Fiber Reinforced Polymer to Die-Cast Magnesium	Keerti Kappagantula (PNNL)	6-38	3.13	3.50	2.88	3.33	**3.31**
mat142	Metal-Matrix Composite Brakes Using Titanium Diboride	Glenn Grant (PNNL)	6-41	3.17	3.42	3.25	2.83	**3.26**
mat146	Ultra-Lightweight, Ductile Carbon-Fiber Reinforced Composites	Vlastimil Kunc (ORNL/Ames Laboratory)	6-46	3.13	3.25	3.13	3.00	**3.17**
mat147	Continuous-Fiber, Malleable Thermoset Composites with Sub-1-Minute Dwell Times: Validation of Impact Performance and Evaluation of the Efficacy of the Compression Forming Process	Gabriel Ilevbare (Idaho National Laboratory)	6-50	N/A	N/A	N/A	N/A	**N/A**
mat149	Non-Rare Earth Magnesium Bumper Beams	Scott Whalen (PNNL/LBNL)	6-51	3.13	3.38	3.25	2.88	**3.23**
mat151	Phase-Field Modeling of Corrosion for Design of Next-Generation Magnesium-Aluminum Vehicle Joints	Adam Powell (Worcester Polytechnic Institute/ LANL)	6-55	2.88	3.00	3.25	3.25	**3.03**
mat152	A Hybrid Physics-Based, Data-Driven Approach to Model Damage Accumulation in Corrosion of Polymeric Adhesives	Roozbeh Dargazany (Michigan State University/ NREL)	6-59	3.50	3.75	3.75	3.50	**3.66**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat153	Multi-Scale Computational Platform for Predictive Modeling of Corrosion in Aluminum-Steel Joints	Miki Banu (University of Michigan/ ORNL)	6-62	3.50	3.33	3.33	3.33	**3.38**
mat162	Machine Learning and Supercomputing to Predict Corrosion/Oxidation of High-Performance Valve Alloys	Dongwon Shin (ORNL)	6-65	3.00	3.10	3.10	2.90	**3.05**
mat163	Multiscale Modeling of Corrosion and Oxidation Performance and Their Impact on High-Temperature Fatigue of Automotive Exhaust Manifold Components	Mei Li (Ford)	6-69	3.30	3.20	3.10	3.30	**3.23**
mat164	Multiscale Development and Validation of the Stainless Steel Alloy Corrosion (SStAC) Tool for High-Temperature Engine Materials	Michael Tonks (University of Florida)	6-73	3.50	3.40	3.60	3.40	**3.45**
mat165	Directly Extruded High Conductivity Copper for Electric Mahcines	Glenn Grant (PNNL)	6-78	3.67	3.50	3.67	3.33	**3.54**
mat166	Aluminum Purification and Magnesium Recovery from Magnesium-Aluminum Scrap	John Hryn (ANL)	6-81	3.67	3.67	3.33	3.50	**3.60**
mat167	Corrosion Mechanisms in Magnesium-Steel Dissimilar Joints	Vineet Joshi (PNNL)	6-84	3.40	3.30	3.60	3.20	**3.35**
mat168	Low-Cost Resin Technology for the Rapid Manufacture of High-Performance Reinforced Composites	Henry Sodano (Trimer Technologies, LLC)	6-87	3.50	3.50	3.50	3.33	**3.48**
mat169	Short-Fiber Preform Technology for Automotive Part Production	Dirk Heider (Composites Automation, LLC)	6-91	3.25	3.50	3.50	3.50	**3.44**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat170	Embedded Networked Elements for Resin Visualization and Evaluation (NERVE) System for Intelligent Manufacturing of Multifunctional Composites for Vehicles	Amrita Kumar (Acellent Technologies, Inc.)	6-94	3.17	3.17	2.67	3.17	**3.10**
mat171	Discontinuous Low-Cost Carbon Fiber/Bamboo Fiber Hybrid Intermediates for Lightweighting Vehicle Applications	David Knight (Resource Fiber, LLC)	6-97	3.25	3.25	3.25	3.00	**3.22**
mat172	High-Performance Fiber-Reinforced Vitrimer Composites through Compression Molding	Yinghua Jin (NCO Technologies, LLC)	6-99	3.17	3.00	3.33	2.83	**3.06**
mat173	Self-Sensing Fiber-Reinforced Composites	Christopher Bowland (ORNL)	6-102	3.50	3.50	3.00	3.50	**3.44**
mat174	Carbon-Fiber Technology Facility (CFTF)	Merlin Theodore (ORNL)	6-105	3.17	3.17	3.33	3.17	**3.19**
mat175	Novel Materials for Polymer Composite Engine Blocks	Amit Naskar (ORNL)	6-108	3.00	3.00	2.88	1.50	**2.80**
mat176	Advanced Anticorrosion Coatings on Lightweight Magnesium Alloys by Atmospheric CO2 Plasma Treatment	Gyoung Gug-Jang (ORNL)	6-112	3.50	3.71	3.50	2.50	**3.48**
mat177	Novel Aluminum Matrix Composite for Powertrain Applications	Zhili Feng (ORNL)	6-117	3.00	2.83	3.42	2.25	**2.88**
mat179	Development of High-Temperature Sample Environment for Advanced Alloy Characterization Utilizing High-Speed, Micron-Resolution X-Ray Imaging Techniques	Dileep Singh (ANL)	6-123	3.70	3.50	3.10	3.00	**3.44**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat180	Reducing The Weight of Vehicle Components via Lost-Foam Casting of Ductile and Austempered Ductile Iron	Sarah Jordan (Skuld)	6-127	3.00	3.00	3.50	3.25	**3.09**
mat182	High-Strength Aluminum-Graphene Composite for Powertrain System	Xiao Li, (PNNL)	6-130	3.50	3.63	3.25	3.25	**3.50**
mat183	High-Temperature Coatings for Valve Alloys	Sebastien Dryepondt (ORNL)	6-133	3.50	3.33	3.67	3.00	**3.38**
mat184	Development of Cast, Higher Temperature Austenitic Alloys	Michael P. Brady, Yuki Yamamoto (ORNL)	6-137	3.63	3.50	3.25	3.25	**3.47**
mat185	Additively Manufactured Interpenetrating Composites (AMIPC) via Hybrid Manufacturing	Derek Splitter (ORNL)	6-142	3.50	3.70	3.70	3.30	**3.60**
mat186	Modeling of Light-Duty Engines	Charles Finney (ORNL)	6-148	2.75	3.38	3.38	3.13	**3.19**
mat187	Fundamental Studies of Complex Precipitation Pathways in Lightweight Alloys	Dongwon Shin (ORNL)	6-152	3.63	3.50	3.38	3.38	**3.50**
mat188	Properties of Cast Aluminum-Copper-Manganese-Zirconium Alloys	Amit Shyam (ORNL)	6-155	3.75	3.50	3.25	3.00	**3.47**
mat189	Fundamental Development of Aluminum Alloys for Additive Manufacturing	Alex Plotkowski (ORNL)	6-157	3.33	3.50	3.50	3.33	**3.44**
mat190	Oxidation Resistant Valve Alloys	G. Muralidharan (ORNL)	6-160	3.67	3.67	3.67	3.50	**3.65**
mat191	Overview of Advanced Characterization within the Powertrain Materials Core Program	Tom Watkins (ORNL)	6-163	3.13	2.75	3.00	2.75	**2.88**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat192	Fundamentals of Austenitic Alloys via Additive Manufacturing	Sebastien Dryepondt (ORNL)	6-167	3.25	3.50	3.00	3.13	**3.33**
mat193	Higher Temperature Heavy-Duty Piston Alloys	Dean Pierce (ORNL)	6-171	3.50	3.67	3.50	3.33	**3.56**
mat194	Accelerated Design of Alumina-Forming, High Temperature Austenitic Alloys	Dongwon Shin (ORNL)	6-175	3.10	3.30	2.80	3.38	**3.20**
Overall Average				**3.29**	**3.31**	**3.30**	**3.14**	**3.28**

Presentation Number: mat118
Presentation Title: Functionally Designed Ultra-Lightweight Carbon-Fiber Reinforced Thermoplastic Composites Door Assembly
Principal Investigator: Srikanth Pilla (Clemson University)

Presenter

Srikanth Pilla, Clemson University.

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

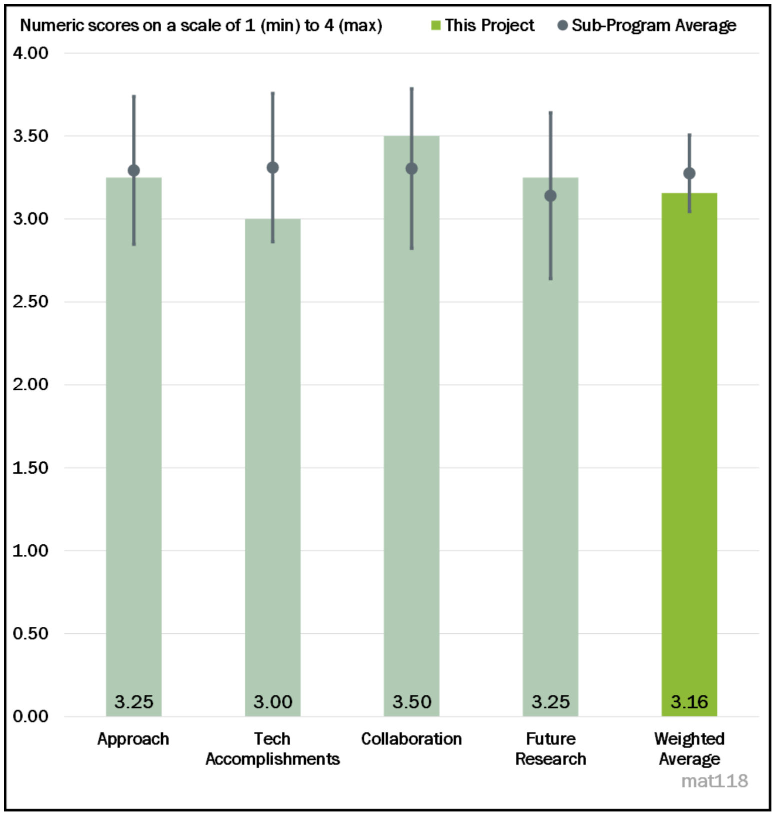

Figure 6-1 - Presentation Number: mat118 Presentation Title: Functionally Designed Ultra-Lightweight Carbon-Fiber Reinforced Thermoplastic Composites Door Assembly Principal Investigator: Srikanth Pilla (Clemson University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Clemson University is teamed up with the University of Delaware (UD) and Honda North America to design and fabricate ultra-lightweight carbon fiber (CF) reinforced thermoplastic composites for door assembly. The approach is novel, and the results are solid and have met U.S. Department of Energy (DOE) targets.

Reviewer 2:

The approach as detailed by the authors seems adequate.

Reviewer 3:

The research team has made a strong effort to address the primary Vehicle Technologies Office (VTO) goals related to component weight saved and the cost per unit of weight saved. The innovative use of fiber reinforced thermoplastic matrices with lightweight aluminum (Al) and strategic use of steel demonstrate a holistic approach that suggests a strong understanding of material selection and application.

While the use of steel for the intrusion beam is a bit of a sidestep related to the most demanding structural aspect of the door, the projected weight targets met through part consolidation/elimination is applauded.

Material cost of carbon fiber reinforced nylon was a significant concern for the research team, to which the reviewer asked why this choice was made versus alternative technologies that include nylon reaction injection molding (RIM) systems that might mitigate cost through a pre-process to create input materials at a lower total cost. This review would further suggest that industrial carbon fibers used in high volume applications are now significantly lower than the noted $7/lb.

Reviewer 4:
The four-phase approach addresses the major areas of automotive door design. The one shortcoming in the approach was having the material characterization plan based on flat plaque samples that repeatedly have been shown to be optimistic compared to material properties of shaped parts.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project has achieved many milestones with significant progress toward the overall project objective. The team lays out a pathway to mitigating the risks.

Reviewer 2:
The research team is a partial victim of the COVID situation because current conditions on campus and within industry challenge progress. However, this is now into year five and molding tools have not yet become part of the program, which appears to be lagging. Nonetheless, progress on achieving goals related to design and manufacturing feasibility is noteworthy and commended.

While the cost goal has not been met, the research team projects a cost penalty of $5.40/lb of weight saved. It would be worthwhile to challenge the material suppliers—what carbon cost is needed to achieve the $5/lb of weight saved target? Is this design feasible if one projects a carbon fiber cost of $5.50/lb?

Reviewer 3:
The reviewer observed solid progress on the technical accomplishments. However, neither the mass reduction nor the additional cost per pound saved targets were met. The project fell 5% short of the mass reduction at a cost per (insufficient) mass saved that was $0.40 more than the target. The performance from the tests reported was satisfactory to this reviewer.

Reviewer 4:
Good progress has been made in the work. Techno-economic analyses of the final door production and cost seem to be missing, based on results from the authors' work, not on projections. Any supply chain issues have not been mentioned or addressed. The reviewer noted that the woven carbon fiber cloth was obtained from a supplier and inquired about how this is expected to affect final cost of the door. Is this supplier a sole supplier? If so, how might this affect tech-to-market transfer of this technology? The reviewer also noted that there is no word on durability of the carbon fiber laminates over time in component form.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Excellent cooperation between all partners to design, analyze, and soon produce the prototype doors for testing. Solid design and adequate cost model show that the design meeting the first performance targets cannot meet the mass reduction or cost targets.

Reviewer 2:
It appears the research team did a very good job leveraging each member's capabilities. From the material selection process and manufacturing simulations (led by Clemson) to the dynamic structural analysis (University of Delaware) and the door component requirements (Honda North America), the team is well balanced and does not appear to suffer paralysis due to lack of project management and coordination.

Reviewer 3:
Collaborators seem to be well coordinated.

Reviewer 4:
The collaboration has been going well among Clemson University, University of Delaware, and Honda North America. The team consists of scientists and engineers with rich knowledge and required expertise in the cross-cutting areas of design, manufacturing, carbon fiber composites, and mechanical testing.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The proposed research makes sense and the previous success opens new possibilities and pathways to further reduce weight and cost.

Reviewer 2:
Future work follows the approach to test the prototype door. This reviewer also requested that the actual mass of each prototype door tested is documented.

Reviewer 3:
The research team appears to have its work cut out for them now. With the door design apparently complete, it is disappointing that work remains on tool and fixture design, but the payoff is in sight with a clear path forward toward composite thermoforming activities and door assembly. There appears to be no reason why this team should be unsuccessful molding and completing the door assembly and testing.

It would be helpful for the researchers to step through the cycle time for primary operations to validate the 20,000-unit annual production rate goal.

Reviewer 4:
Techno-economic analyses based on project results seem to be missing.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The ultra-lightweight, carbon fiber-reinforced, thermoplastic composites door assembly that was developed supports overall DOE objectives and should find immediate applications in vehicle structures and other components.

Reviewer 2:
This work is relevant to the overall goal of vehicle lightweighting.

Reviewer 3:
Mass reduction at affordable costs will help reduce fuel consumption and reliance on imported oil.

Reviewer 4:
Yes, the project does support overall objectives for improving energy use in commercial automotive applications. The stated objective to reduce the mass of this automotive component (common to all commercial automobiles) of at least 42% will likely be met because of this research work. Furthermore, DOE's stated cost objective is no more than an incremental cost of $5/lb of weight saved. The research team is projecting a cost penalty that is approximately 8% higher at $5.40 per lb of weight saved. The reviewer opined that the cost basis assumed by the research team is modestly high; given volume projected and the direction of material costs for industrial carbon fiber declining, the accomplishments achieved in the present work are both commendable and support DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The research team appears able to accomplish its stated goal of manufacturing the door components with currently available funds. The creation of such a complex system at funding levels of approximately $6 million is notable. The level of cost share is similarly commendable and demonstrates great confidence in the commercial value of this technology.

Reviewer 2:
Funds seem sufficient to complete this work based on information provided by the authors.

Reviewer 3:
The team leverages resources from Clemson University, University of Delaware, and Honda North America. The project is making progress toward the stated milestones in a timely manner.

Reviewer 4:
Sufficient resources were observed by this reviewer.

Presentation Number: mat122
Presentation Title: Close-Proximity Electromagnetic Carbonization (CPEC)
Principal Investigator: Felix Paulauskas (Oak Ridge National Laboratory)

Presenter

Felix Paulauskas, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

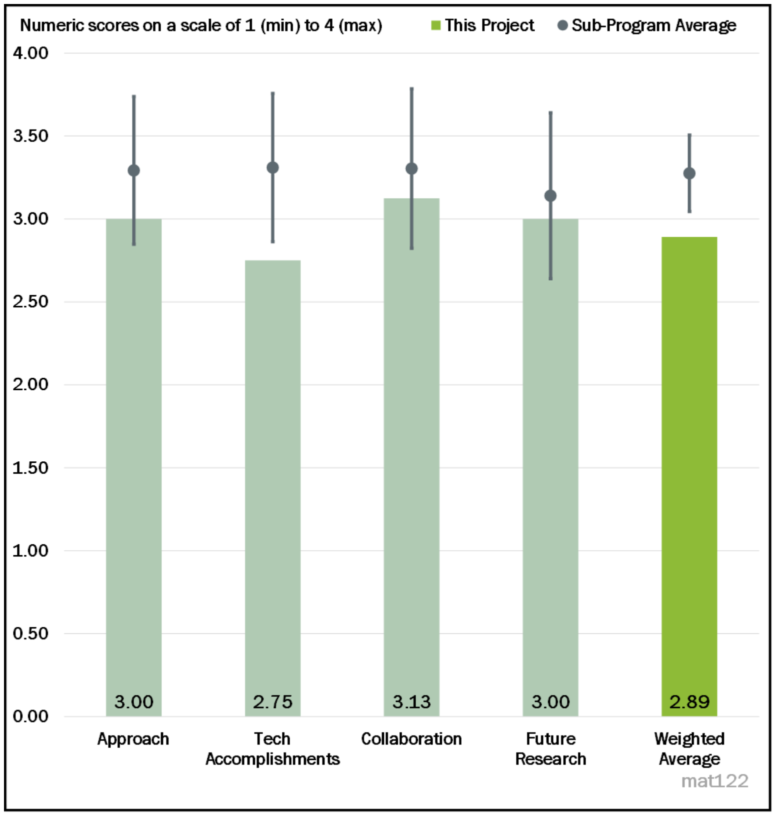

Figure 6-2 - Presentation Number: mat122 Presentation Title: Close-Proximity Electromagnetic Carbonization (CPEC) Principal Investigator: Felix Paulauskas (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The team proposed using a Close Proximity Electromagnetic Carbonization (CPEC) technique to shorten carbonization time and lower carbonization temperature, which is a creative approach. The project started from scratch with many challenges and is progressing toward its overall project goal.

Reviewer 2:

The Oak Ridge National Laboratory (ORNL) research team appears to have created a logical approach and a novel method for addressing the energy intensive and long dwell times for carbon precursor low-temperature carbonization. Developing computational electromagnetic modeling to inform the process is significant and important for overall success. Progress suggests the proposed methods are feasible, but hardware failures imply that this has yet to be fully proven.

Reviewer 3:

This work has been in the making for a couple of years and it is a challenging problem. The approach involves low-temperature carbonization through electromagnetic carbonization. The project team’s overall goal is 50% cost reduction for carbon fiber manufacturing with comparable performance. The team is looking at coupling the energy through electromagnetics to convert precursor during carbonization and minimize energy losses in the furnace. The project team’s designs have evolved through multiple iterations to what is referred to as CPEC-4 with additional configurations added in the current year. While the project team had evidence of carbonization, there was some failure in the cavity. It appears more challenges were encountered in the CPEC-4 in conjunction with the additional configurations.

Reviewer 4:
The project depends on hardware that the team found to be non-conforming to certain phase control specifications; subsequently, this issue has created significant delays. The exact source of the issue is unclear to this reviewer, but reliance on a single piece of equipment points to potential fundamental barriers in deploying the technology and scaling it up in the future.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The CPEC-4 processing system was ultimately able to show evidence of carbonization, and the project was extended for one year while the hardware issues are sorted out.

Reviewer 2:
The project team designs have evolved through multiple iterations to what is referred to as CPEC-4 with additional configurations added in the current year. While the project team had evidence of carbonization, there was some failure in the cavity. It appears more challenges were encountered in the CPEC-4 in conjunction with the additional configurations. The project team seems to have had a non-conformable generator and is working toward replacing it with a new unit. Results from bringing this on-line will provide more indication of the process' successes, which are not entirely clear, presently. The project team is in the process of evaluating and modeling the new configurations. The number of tows that eventually can be successfully incorporated is unclear at this stage.

Reviewer 3:
The project needs to have new equipment that is not available in the market. The team did theoretical analysis and design of the CPEC equipment, including key components, and has demonstrated the feasibility of carbonizing polyacrylonitrile (PAN) fibers using the electromagnetic method. The reviewer commented that further optimization and scale up proceed.

Reviewer 4:
The hardware setbacks certainly frustrate project progress. However, the processing performed prior to the CPEC-4 cavity failure suggests that process goals are likely to be attained. This reviewer would have indicated more comfortable if the specific cause of the unit failure was identified. There remains some mystery around whether model assumptions, supplier failure to meet performance specifications, or anomalies in the precursor inputs are at fault. This suggests that significant technology gaps remain, which should not be too surprising given the technical readiness level of this important work. The team appears to have a path forward, it has already recovered from the CPEC-4 failure, and that should be recognized.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The 4X Technologies (4X) and ORNL teams are experts in the work and the collaboration is appropriate and very well structured.

Reviewer 2:
The reviewer observed very good collaboration and coordination across the project team. The team leverages the resources at ORNL and 4X.

Reviewer 3:
The collaboration between ORNL and 4X seems appropriate.

Reviewer 4:
This reviewer scored down the collaboration simply because of the apparent differences that have occurred over the supply of equipment to the ORNL research team. When a 2-month period of negotiation is required after a significant equipment failure, this indicates that a program fault may exist. In this case, it clearly has stalled progress.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The proposed future research makes sense and lays out a pathway to mitigating the risks in scaling up electromagnetic technique. The reviewer indicated that many tows could be processed, and low-temperature electromagnetic carbonization alone could do entire carbonization without using high-temperature carbonization.

Reviewer 2:
The project is scheduled to close during this fiscal year (FY,) meaning not too much additional proposed work is in order. The project team has indicated that CPEC-4 failure may have been a result of “initial assumptions used in the CEM”. It would be reasonable to expect that the team would seek to validate those assumptions or change the assumptions and validate the model. The reviewer wondered if that is possible and what might be done—beyond simply measuring the resulting fiber—to validate the coulombic efficiency (CE) model output and further inform scaled-up equipment designs. Otherwise, the stated work proposed for FY 2020, including the economic analysis, is important for validating the value of this work.

Reviewer 3:
It appears that the new configurations will need tuning. The new (conformable) generator ought to indicate the success or challenges of carbonization and conversion. A reliable and reproduceable carbon yield needs to be demonstrated for commercial viability. Overall, the approach for the next steps seems reasonable.

Reviewer 4:
Future effort hinges on sorting out hardware problems to achieve normal operation of the CPEC-4. The objective of 4 tows (24,000) with 60-second (s) residence time and 250 kilopound per square inch (ksi)/25 million pounds per square inch (Msi) appears to be part of the proposed scope; however, the volume of material promised and how cost is expected to scale with volume is unclear to this reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
DOE has stated objectives that include improving the economics of high specific property materials. In this class of materials suitable for industrial and commercial application is carbon fiber. CF manufacturing is very energy intensive, which is a significant cost component. The research work presented under this funding has significant potential to reduce the energy requirement and increase material throughput in a capital-intensive environment. This will drive cost down and expand applications for carbon fiber in transportation resulting in energy savings that align with strategic DOE goals.

Reviewer 2:
Low-cost, high-performance carbon fibers are the key for developing lightweight composite structures. The electromagnetic method holds the promise to decrease conversion cost, which this reviewer indicated is the way to reduce the cost of PAN-based carbon fibers for vehicle applications.

Reviewer 3:
The objective of low-cost carbon fiber is in line with DOE objectives.

Reviewer 4:
Reducing energy of manufacture is a key DOE goal. If successful, this project is in the right direction to address this need.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
While the program has been challenged by equipment development, the research team has been meeting program milestones and achieving results through no-cost program extensions. The high-risk, high-reward research and development (R&D) appears to be adequately resourced with meaningful results forthcoming.

Reviewer 2:
The team has sufficient resources at ORNL and 4X for the project to achieve its stated milestones. The project is very challenging (starting from scratch in terms of equipment, which is not available in the market).

Reviewer 3:
The team between ORNL and 4X has the appropriate equipment. Some of the updates proposed will further align with resource needs.

Reviewer 4:
The extra year given to the team to sort out issues is appropriate.

Presentation Number: mat124
Presentation Title: Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber for Lightweight Vehicles
Principal Investigator: Xiadong Li (University of Virginia)

Presenter

Xiadong Li, University of Virginia

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

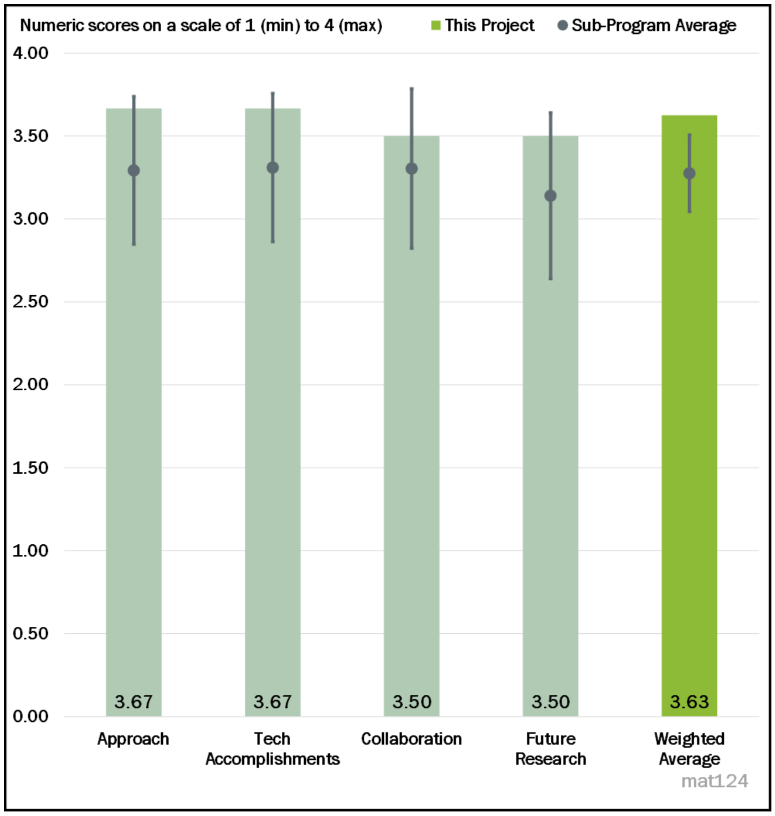

Figure 6-3 - Presentation Number: mat124 Presentation Title: Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber for Lightweight Vehicles Principal Investigator: Xiadong Li (University of Virginia)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Excellent approach to use integrated computational materials engineering (ICME) to identify cost-effective carbon fiber production.

Reviewer 2:

The project uses ICME tools to guide and optimize the manufacturing process for high-quality and cost-effective carbon fiber. Achieved results prove success of the approach. Precursor processing is very complicated, and the project is able to catch critical elements when applying ICME tools. This is very impressive.

Reviewer 3:

Year 3 work has evolved well from the overall project objective, which is to model conversion of fibers and predict properties. The project team has systematically approached modeling the preoxidation, oxidation, and carbonization and predicted coupled thermal-chemical-mechanical fiber transformation. The Year 3 focus has been to optimize work initiated in Year 2; the project team has shown progress in Ultra-high molecular weight polyethylene (UHMWPE), mesophase pitch, and Nylon 6. While ICME reactive force field (ReaxFF) was more developed for the UHMWPE and Nylon 6, the mesophase pitch was more along the lines of experimental characterization via techniques such as polarized light and Raman spectroscopy. The project team carries on continuum modeling for various pore sizes, geometries, orientations, etc., to refine the predicted properties and core-shell nanostructures.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Excellent accomplishments on the various precursors, UHMWPE, pitch, various nylons, and the ICME framework. Good summary of accomplishments against DOE targets.

Reviewer 2:
The project has integrated ReaxFF, molecular dynamic (MD) analysis, continuum finite element analysis (FEA), and other computer-aided engineering (CAE) tools to optimize the fiber recipes, maximize properties, reduce conversion time, and reduce precursor and conversion costs. The project has demonstrated technologies and successfully produced high-quality and low-cost carbon fiber in the lab.

Reviewer 3:
Some of the comments made previously apply here. Year 3 work has evolved very well from the overall project objective, which is to model conversion of fibers and predict properties. Technical accomplishments on the ReaxFF modeling of the UHMWPE and PA6, as well as comparisons to the experiments were described by this reviewer as in-depth. The alternate precursors work in these forms is on target per the scope of the work. Progress is demonstrated adequately through performance indicators and metrics. Although the role of the core-shell nanostructures was not fully clear, the work is aligned with the overall scope.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration between research organizations are great. Each research partner contributes to project success with VTO’s leadership.

Reviewer 2:
The team is very well coordinated. The University of Virginia, Pennsylvania State University, ORNL, Solvay, and Oshkosh are well coordinated in the work and each partner has tangible contributions.

Reviewer 3:
The progress indicates excellent collaboration between the five entities. The reviewer expressed interest in seeing a table of how often there was contact, meetings, or reviews between and among the five entities.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The reviewer observed the right next steps to finish the project by September 2020.

Reviewer 2:
The project team’s proposed future research is reasonable. The team looks to do the following logical and reasonable tasks for the proposed future research:

- Finalize ICME framework with ReaxFF and MD simulations.
- Complete continuum finite element (FE) model predictions based on experimentally measured pore size and distribution.
- Complete mechanical testing and characterization of pilot-scale alternative fibers to validate ICME predictions.

Reviewer 3:
The planned future research activities are critical for industrial application of the research results. The reviewer would also like to see further development of ICME tools, especially the integration of more detailed process analysis into optimization when considering scalability.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
DOE is seeking alternate precursors for producing low-cost carbon fiber. This work demonstrates a simulation-based approach backed by excellent experimental work and validation. Hence, it meets DOE goals very well.

Reviewer 2:
Carbon fiber-reinforced polymer composite is one of the most promising materials for vehicle lightweighting. The project has demonstrated technologies and found precursors for high-quality and low-cost carbon fiber. The research will contribute to achieving DOE VTO objectives.

Reviewer 3:
The cost of carbon fiber must be reduced to allow inclusion of carbon fiber-based composites into high-volume automotive products.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Sufficient resources were noted by this reviewer.

Reviewer 2:
The team is very well equipped to conduct the simulation and experimental work.

Reviewer 3:
Although the research involved in the project is expensive, the project has been going well, mostly.

Presentation Number: mat125
Presentation Title: Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber
Principal Investigator: Jeramie Adams (Western Research Institute)

Presenter

Jeramie Adams, Western Research Institute

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

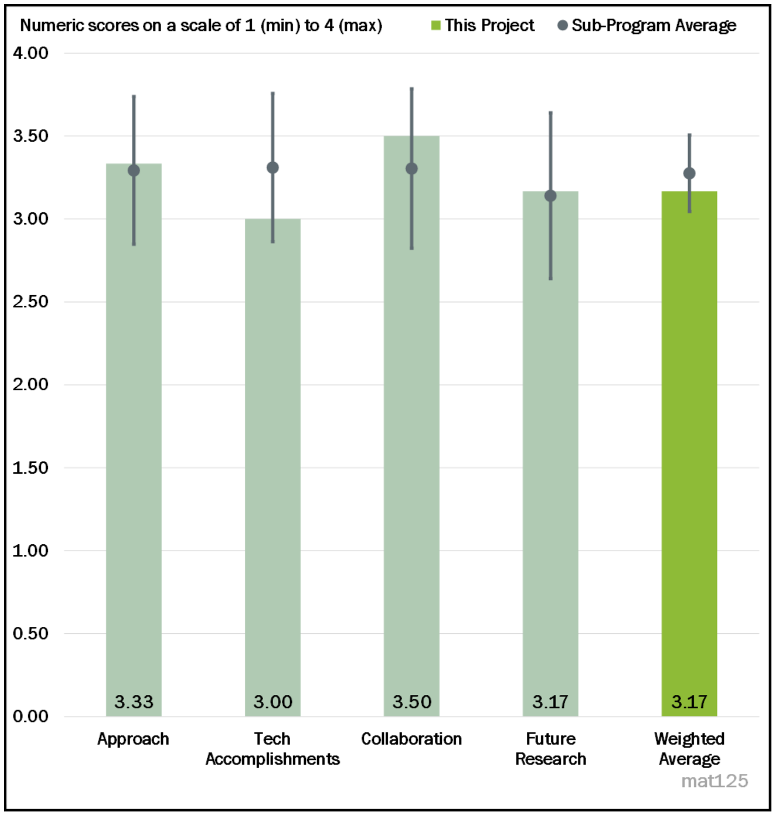

Figure 6-4 - Presentation Number: mat125 Presentation Title: Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber Principal Investigator: Jeramie Adams (Western Research Institute)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Good plans and good progress were highlighted by this reviewer.

Reviewer 2:

Western Research Institute (WRI) teamed up with ORNL, Massachusetts Institute of Technology (MIT), Southern Research Institute (SRI), Advanced Carbon Products (ACP), University of Wyoming (UW), Ramaco Carbon, and Solvay Composites to convert biomass, coal, and petroleum oil to carbon fibers. The project team works on removing impurities to get high-quality carbon fibers, yet that may subsequently increase the conversion cost. How predictable are the mechanical properties on batch-to-batch variation due to impurities?

Reviewer 3:

The reviewer is unable to suggest steps to improve the current approach laid out by the authors.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The team made progress toward overall project. The mechanical properties from bio-acrylonitrile (ACN) met the DOE targets. The pitch-derived carbon fibers showed low strain (below DOE target strain).

Reviewer 2:
This reviewer reported the following technical accomplishments and progress:

- Chemical and physical characterization of feedstocks/intermediates/precursors/mesophase/CF
- Production of scaled-up, multi-filament CF from bio-ACN and mesophase coal tar pitch (CTP)
- Production of scaled-up, bio-polyacrylonitrile (PAN) CF that met DOE requirements
- Developed models to go from the molecules to CF properties and machine learning (ML) models.

Reviewer 3:
All accomplishments in the presentation were labeled FY 2019 accomplishments. Being 8-9 months into FY 2020, the reviewer presumed this is a typographical error, but asked for clarification as to whether the work was suspended for 8-9 months.

The reviewer assumed that this is FY 2019/2020 work that has been presented and expressed interest in seeing techno-economic analyses of the fiber cost with this manufacturing process, including any supply chain issues that may either increase or decrease the fiber cost. The reviewer would also like to see validation of the developed model(s) to make the predictions central to the outcomes, including for the atomistic and micro modeling completed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team has put together a strong multidisciplinary team.

Reviewer 2:
This reviewer noted good collaboration among WRI, ORNL, MIT, SRI, ACP, UW, Ramaco Carbon, and Solvay Composites to leverage resources and expertise.

Reviewer 3:
The reviewer was satisfied with the level of collaboration going on in the project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The proposed research plans for each aspect of the work are strong and consistent with the overall project objectives.

Reviewer 2:
The proposed future research makes sense and the team lays out pathway to mitigate risks such as impurities and conversion costs. A plan is needed for enhancing the strain of pitch derived carbon fiber.

Reviewer 3:
Techno-economic analyses of the process including supply chain issues, as well as model validation, are required.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is highly relevant to the production of affordable carbon fiber for vehicle lightweighting.

Reviewer 2:
The project supports the overall DOE objectives. If successful, the low-cost carbon fibers will find immediate applications in lightweight composites.

Reviewer 3:
The objective of low-cost carbon fiber is consistent with DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources from WRI, ORNL, MIT, SRI, ACP, UW, Ramaco Carbon, and Solvay Composites are sufficient for the project to achieve the stated milestones.

Reviewer 2:
The reviewer observed sufficient resources.

Reviewer 3:
This reviewer commented that there were no budget figure(s) for FY 2020 and FY 2021.

Presentation Number: mat126
Presentation Title: Room-Temperature Stamping of High-Strength Aluminum Alloys
Principal Investigator: Aashish Rohatgi (Pacific Northwest National Laboratory)

Presenter

Aashish Rohatgi, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

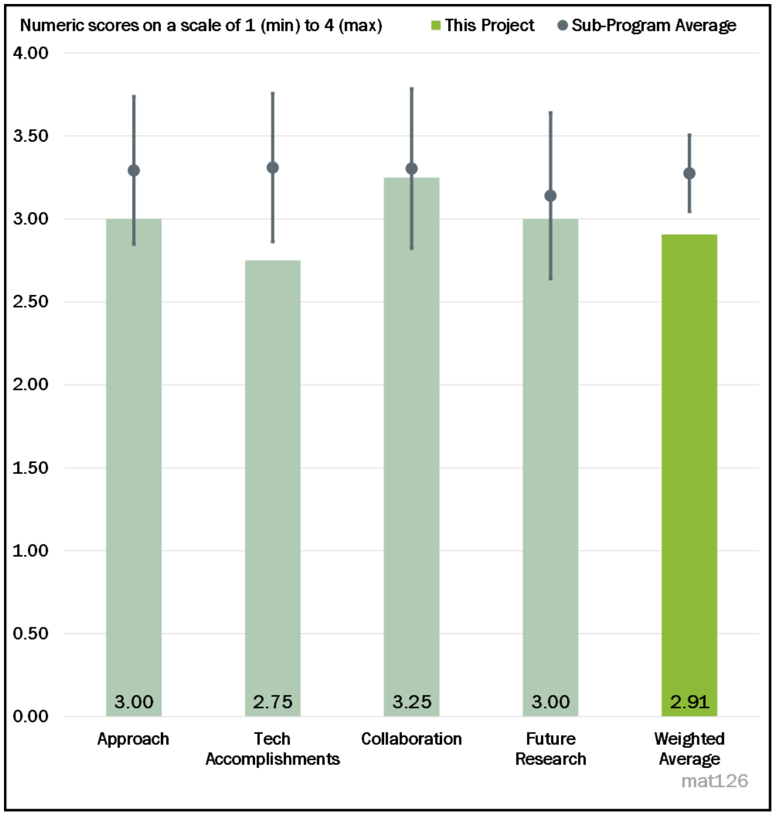

Figure 6-5 - Presentation Number: mat126 Presentation Title: Room-Temperature Stamping of High-Strength Aluminum Alloys Principal Investigator: Aashish Rohatgi (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project will evaluate the forming response of a high-strength aluminum alloy at room temperature; this is tested by keeping the tool at room temperature. All aspects of the process are being modeled and experimental trials are included. Further characterization of the material is in progress. Overall, the technical approach is good.

Reviewer 2:

The project team has undertaken a big challenge of room-temperature stamping of a high-strength 7xxx alloy. The approach towards solving the problem is reasonable; namely, formability improvement while retaining strength.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The modeling of heat treatment including ageing and deformation is completed. Some of the data predicted by modeling was confirmed microstructural evaluation using x-ray and light sources. Experimental verification of the forming process is under progress. Overall, the technical accomplishments are in line with the proposal.

Reviewer 2:
The project team has denoted excessive effort in strength modeling while the formability (or even uniform elongation) aspect has been ignored for modeling. The reviewer hoped the project team can devote some of its remaining time to the latter problem to benefit the broader industry.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer noted a Lightmat project with industry partner (Magna) and described this as a good collaborative effort.

Reviewer 2:
This reviewer observed a DOE laboratory-led project with other labs and at least one Tier 1 supplier involved in the project. Technical input from one OEM is used to define project scope, which will ensure that the outcome will be beneficial for the vehicle manufacturer if it addresses the requirement.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The future research plan is good. Formability modeling (even if empirical) will benefit the effort immensely.

Reviewer 2:
No new research is being proposed as it is near completion. It will be useful to have a publication on the current state of understanding on the low-temperature formability of various aluminum alloys as one of the end products.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Reducing the cost of metal forming process will enable mass use of the light metal parts. It is known that weight reduction will improve fuel efficiency or vehicle range. Energy efficiency and greenhouse gas (GHG) reduction are DOE focus areas and this project will contribute to those goals directly.

Reviewer 2:
Lightweighting benefits and reduced energy consumption (room temperature forming) support DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources are sufficient and the project is nearing completion.

Reviewer 2:
The project is in the last work phase and the delay in work will not impact the total project value. This reviewer added that in-kind contribution from the industry partner is limited.

Presentation Number: mat127
Presentation Title: U.S. Automotive Materials Partnership Low-Cost Magnesium Sheet Component Development and Demonstration Project
Principal Investigator: Randy Gerken (Fiat Chrysler Automotive)

Presenter

Randy Gerken, Fiat Chrysler Automotive

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

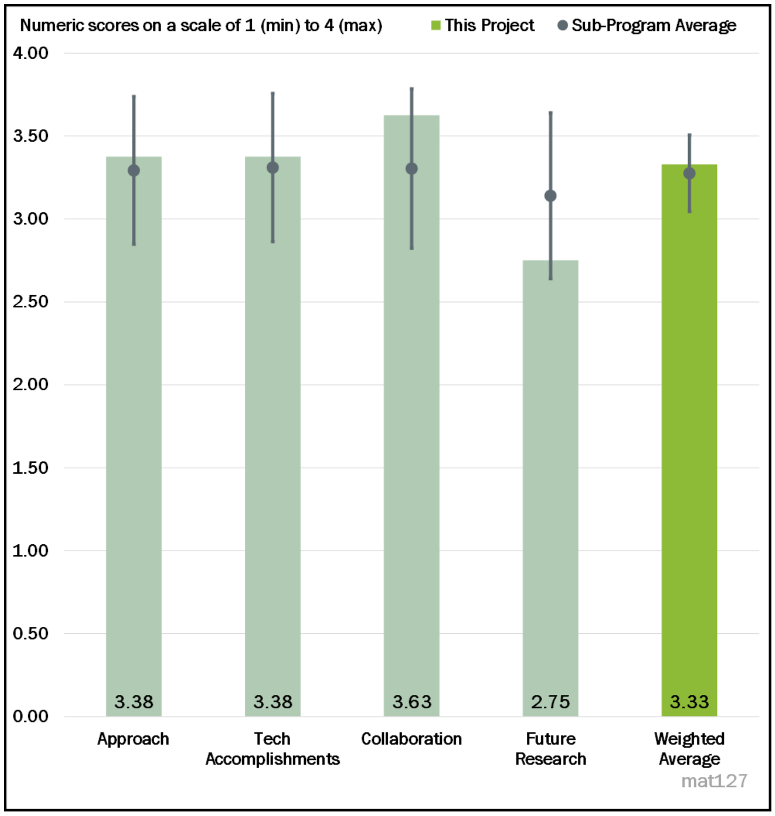

Figure 6-6 - Presentation Number: mat127 Presentation Title: U.S. Automotive Materials Partnership Low-Cost Magnesium Sheet Component Development and Demonstration Project Principal Investigator: Randy Gerken (Fiat Chrysler Automotive)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
Very comprehensive program that encompasses material development, modeling, and testing.

Reviewer 2:
The project has well-designed guidelines to develop sheet magnesium (Mg) alloys that can be made by drawing/stamping process for vehicle applications. The use of ICME methodology for alloy development has become popular in recent years. Subsequently, it would be nice for the project to share its experience on the method's effectiveness as related to the alloy development process. The selection of minor additions (zinc [Zn], Al for strength, cerium [Ce], tin [Sn], calcium [Ca] for texture, etc.) to the alloy is reasonable. The effort to correlate texture with formability is important and the right direction to go.

Reviewer 3:
All aspects of Mg sheet performance are being studied including alloy content, texture during forming, joining, and corrosion, which are the major factors influencing Mg sheet use.

The alloy is considerably lean but has many elements including some rare earth elements (REE) at comparatively low level. This is good for the cost but recycling of this sheet at the end of life may be complicated.

Development of modeling capability is useful.

Reviewer 4:
The project appears to be well managed, which is difficult with such a large group. The researchers have identified the main issues—formability and compatibility with downstream processes like paint. Most of the work is aimed at making new alloys, but the demonstration and prototype work will occur with a commercial alloy, which is disappointing. The value of the ICME work may be proven years down the road, but currently, the proof of concept work will be on the commercial alloy, which implies the bulk of the work was unnecessary.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Overall, good progress was noted by this reviewer. Business decision on material supply influenced the timing, which is understandable under the circumstances. The reviewer also highlighted excellent progress on formability modeling and validation.

Reviewer 2:
The reviewer observed an effort to develop new alloys even though the work is not concentrating on one existing alloy, E-Form Plus. The rationale for this approach to develop new ones is not explained. However, one of the new alloys exhibited high strength after T6 treatment. This may be a good outcome as far as Mg alloys are concerned. This wrought alloy needs to be studied further for other processes, including forging and extrusion.

The coating and corrosion study has established operating procedures and needs to be studied further for larger components; the observation is same for joining techniques.

Reviewer 3:
Progress is being made, but slow work on the alloys and trying to match the E-Form alloy already commercialized seems to be a big drawback. The reviewer observed significant time and effort spent on making new alloys, when something already available is better than what the project team is working on currently. The use of ICME tools is nice and the predictions are matching some of the experimental results, but this all may be for naught. This reviewer would have liked to see more quantitative data on the corrosion testing (scribe creep, undercutting, etc.). Also, how compatible are the paint shop pretreatments with a mixed metal body structure? Is there a maximum amount of Mg, Al, or steel that can be processed through a bath with the new cleaners and pretreatments that were developed? Is the scribe creep performance of Al and steel (cold-rolled steel [CRS] and electrogalvanized [EG]) comparable to today's performance with zinc phosphating (ZnPhos) or zirconium sub-oxide (ZrO_x)? The reviewer asserted the need to see data on that.

Reviewer 4:
One of the major project goals seems to focus on cost (increase over conventional steel-stamped components of no more than $2.50/lb saved), but not much information regarding cost is shown in the report. The reviewer hoped it will be reported in the next stage of research. It is not clear how the crystal-plasticity model is being used to correlate the microstructure to formability of the alloy. The resource needed to pursue that direction is often underestimated.

In the in situ X-ray experiment, the alloy (E-Forming Plus) identified/developed from this project was not used, but two Mg-Sn/Mg-Ca system, which seems to show poor mechanical property. Is there a particular reason not to use E-Forming Plus? Also, the high-energy diffraction microscopy (HEDM) technique is very unique and powerful but has its limitations. Does the specimen have the suitable grain size/microstructure for this technique?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
It appears that there is excellent collaboration among the team. Data are being shared and used by the various team members at different institutions. This looks like a strong suit of the project.

Reviewer 2:
The presenter clearly acknowledged the multiple partners and their efforts during the program. There is an excellent balance between the industry partners, including major original equipment manufacturers (OEMs), suppliers, and university members.

Reviewer 3:
Three OEMs with suppliers, universities, and DOE laboratories are involved in this study, making it easy for dissemination of knowledge. Each participant role is clearly defined, and the presentation highlights each member's progress. Good work.

Reviewer 4:
Team partners are well balanced and cover academia and industry.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
Generally, the project team has done a good job, but this reviewer questioned the need for all the alloy development if the project teams already has an alloy that works. It seems the project team should have pivoted to something different or deferred some of the research once it had an alloy that met most of the team's goals. It is unclear what the project team will do with the new alloys under development or what will be their advantages.

Reviewer 2:
The budget and future work plan is appropriate. The project is in the final stretch; even though technical tasks are completed, there is no defined path for future production and use. This will be a failure on the project as findings are not used immediately.

Reviewer 3:
It would be helpful to update the cost model to illustrate the cost of the demonstrator door part.

Reviewer 4:
The project indicates "Develop test methods to characterize anisotropy in Mg sheet as current standardized tests were determined to be ineffective" as the remaining barrier. Is there any effort proposed in FY20/FY21 to address this problem?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project support's DOE's lightweighting efforts for automotive and transportation structures. It supports new, innovative materials and their manufacturing to offer additional tools to meet aggressive weight targets meeting cost constraints. The project employs many partners that address many of the downstream requirements (bonding, painting, welding, joining) that are commonly not evaluated on new material development applications.

Reviewer 2:
The reviewer agreed that this is relevant to VTO's objective of developing material/process to advance vehicle-related technology.

Reviewer 3:
Yes, the work does support goals—lighter weight and thus, improved fuel economy.

Reviewer 4:
Magnesium is proven to reduce vehicle weight and can contribute to overall GHG reduction and fuel consumption. Magnesium sheet can be used in many applications, both internal and structural; however, the future process of mass sheet production is not certain.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Acknowledging that the project team got an 11-month extension due to some supplier issues, the project appears to have a good team and sufficient resources to complete its task on time.

Reviewer 2:
The reviewer observed a complete plan and sufficient funding during the last year of work, and noted that the project is on no-cost extension.

Reviewer 3:
Project employed the right team members to effectively address bonding, painting, and coating technologies.

Reviewer 4:
The project consists of teams with diverse background and experience.

Presentation Number: mat136
Presentation Title: High-Performance Computing and High-Throughput Characterizations toward Interfaces-by-Design for Dissimilar Materials Joining
Principal Investigator: Xin Sun (Oak Ridge National Laboratory)

Presenter

Xin Sun, Oak Ridge National Laboratory; Ayoub Soulami, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

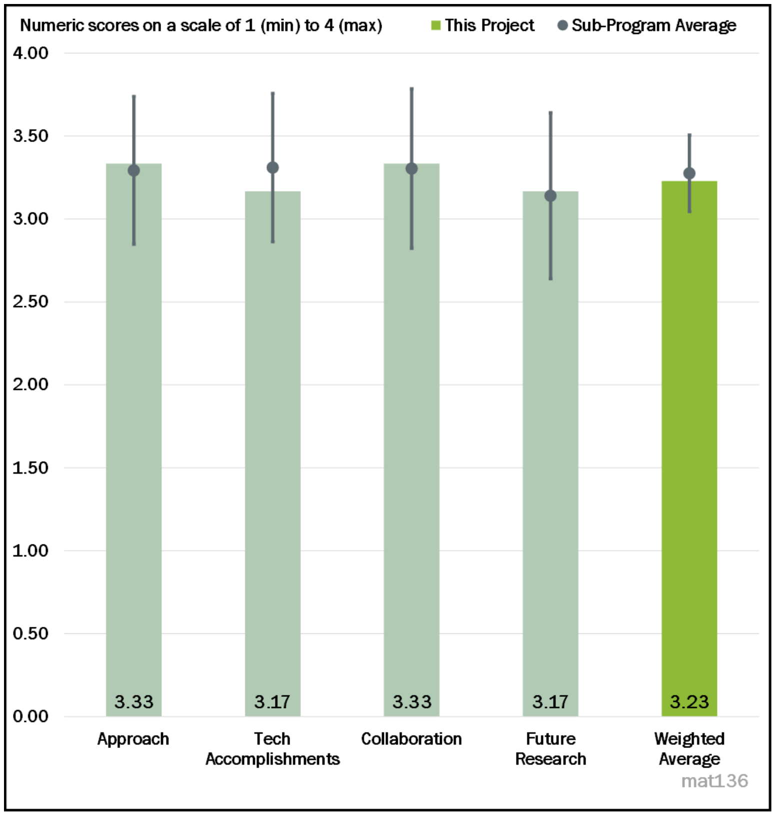

Figure 6-7 - Presentation Number: mat136 Presentation Title: High-Performance Computing and High-Throughput Characterizations toward Interfaces-by-Design for Dissimilar Materials Joining Principal Investigator: Xin Sun (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The design team's approach by the interface is strong.

Reviewer 2:

Although very good work has been done developing tools and approaches on multiple fronts (ultrasonic welding, friction stir welding, adhesive bonding) as exemplified by the content of the presentation, the reviewer opined that this project is extremely broad and suffers from a lack of sufficiency in any given area. For example, the project team has been able predict bond strength/failure modes at the Mg/iron (Fe) interface, but this is after the fact of the experimental work. How can this model now be used to drive the process development work? Great potential is seen in these tools, but they need to be applied to understanding the fundamental problem to drive the experimental work. However, the team has made significant contributions given limited resources and breadth of focus. If there is a step two in this initiative, then a narrower technical focus (or added simulation resources) should be identified to create the critical mass needed to move a given joining technology forward.

Reviewer 3:

This reviewer asked how the work performed at ORNL and Pacific Northwest National Laboratory (PNNL) could be linked. There may exist some similarities between the different processes, and the generated knowledge may be applied across the process at a certain level. For example, the material models could follow the same governing laws under thermomechanical loads for different processes.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Good progress was achieved on the Mg-to-coated steel interface including experimental and computational efforts.

Reviewer 2:
The team accomplished the milestones mentioned. Novelties of the work could be highlighted in the future presentation.

Reviewer 3:
The team has clearly presented the interface by design framework for the Mg/Fe interface applying a diffusion/solidification model for Zn-coated steels and subsequent mechanical properties/fracture based on microstructure. The reviewer highlighted this as a prime example of the first step in interface by design. The inverse FE approach coupled with digital image correlation (DIC) leverages the power of the DIC-generated data. However, it is not clear how this could help understand the effects of surface treatments applied to improve adhesive bonding.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Strong collaboration among the various teams.

Reviewer 2:
The ability to complete an inverse FE approach requires clear communication with the experimental team. The ability to model the Mg/Fe interface microstructure and fracture requires detailed experimental work and close collaboration of the teams. The project results presented clearly demonstrate a close collaboration. However, the true test of collaboration and coordination is when these models are used to direct the experimental work. Looking forward to a continued Phase 2 where the tools developed in this project are applied in this regard.

Reviewer 3:
PNNL and ORNL are working on different processes. Within one process, the simulation and experimental groups collaborate well.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
Given that the project is expected to be completed by September 2020, the team goals listed on Slide 20 are reasonable and appropriate.

Reviewer 2:
This reviewer reported that proposed future research is contingent on funding levels according to the presenters.

Reviewer 3:
Noting that the project will finish September 2020, the reviewer indicated that future work seems too much to finish in such a short time.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Multimaterial joining is a critical technology for DOE.

Reviewer 2:
This project supports lightweighting technologies by joining dissimilar lightweight metals.

Reviewer 3:
This project has developed numerical-based tools that elucidate the fundamental physics ongoing at the interface of dissimilar material joints fabricated with a range of processes. This fundamental understanding can then be applied to improve the joining processes to achieve optimum joint strengths and process robustness, which then are of industry interest to implement multi-material, mass-saving constructions.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The team is well prepared with required recourses, including joining process, characterization techniques, and simulation tools.

Reviewer 2:
Appropriate resources are available to complete the work.

Reviewer 3:
The project team has achieved its milestones such as demonstration of the interface by design framework on the Mg/Fe joint and experimental/numerical work on the adhesively bonded joints.

Presentation Number: mat137
Presentation Title: Adhesive Bonding of Carbon-Reinforced Plastic to Advanced High-Strength Steel
Principal Investigator: Zhili Feng (Oak Ridge National Laboratory)

Presenter

Zhili Feng, Oak Ridge National Laboratory; Kevin Simmons, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

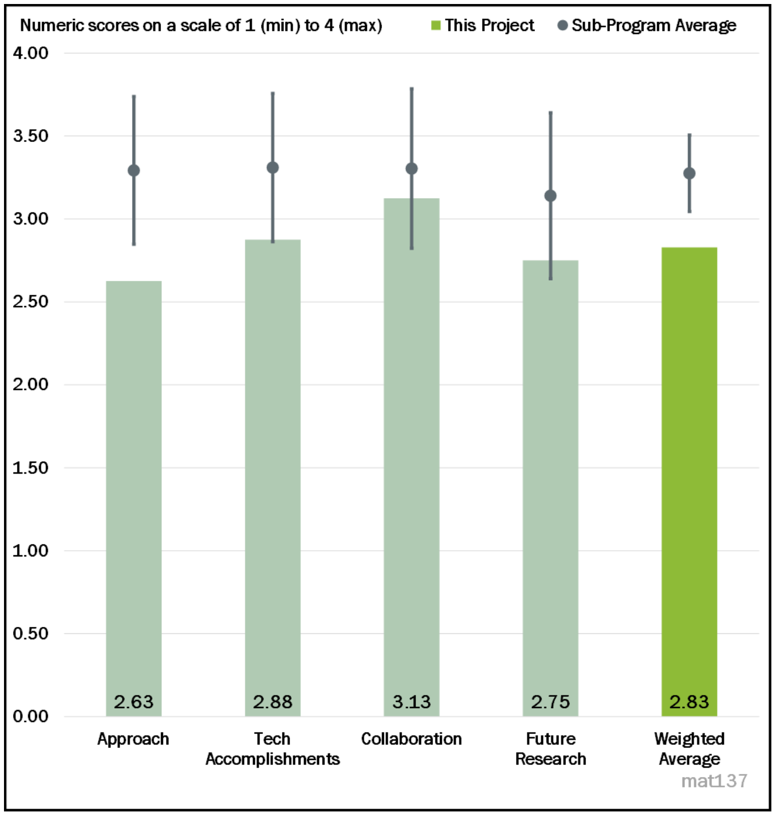

Figure 6-8 - Presentation Number: mat137 Presentation Title: Adhesive Bonding of Carbon-Reinforced Plastic to Advanced High-Strength Steel Principal Investigator: Zhili Feng (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The technical approaches are well planned to achieve the milestones. This reviewer asked why the surface compositions are similar in both silane-treated steel and carbon fiber reinforced polymer (CFRP).

Reviewer 2:

The work is in an important area and being carried out in a professional manner. It is not fully clear to the reviewer that this is addressing questions of either fundamental or practical interest. If this is to be practical, it would be advisable to have a larger industry presence and be informed of current design approaches and barriers. If fundamental, greater insight onto the physical chemistry and micromechanics of the adhesive/interface system would be welcome.

Reviewer 3:

There is a significant body of literature showing the benefit of plasma-based silane coatings and laser ablation, which this work reproduces. This project attempts to address too broad of a focus given the resources available. The micro-DIC work at the interface is novel and adds to the current body of knowledge, which is exciting. The reviewer would have liked to see the following: how the interface by design models the change in bond strength with and without the silane surface; how removal of the resin-rich outer layer by plasma or laser ablation affects both surface roughness and chemical bonding; and the relative effects of both. This is an ideal problem to be solved numerically and then validated experimentally.

Reviewer 4:
The main work thrust appears to be surface modification of the CFRP and the steel. This can improve the bond strength potentially, but does not address the main issue of thermal distortion and mismatch in coefficient of thermal expansion (CTE) between the two materials. It is hard to understand how the project team approach will enable these materials to be used together when part distortion is a huge concern. The coupons used by the team are not of sufficient size to understand the residual stresses and strains that will occur when these materials are joined together and subjected to a paint bake.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The team is making solid progress on many fronts including interface development, local chemistry, and mechanics. There is a lack of reporting on published papers or presentations, which represent clear metrics on productivity.

Reviewer 2:
The results are interesting and significant increases in bonding strength are seen. However, there is only one presentation on this work, to which this reviewer suggested that there may be other working papers not included in this review presentation.

Reviewer 3:
The researchers appear to understand surface modification and surface characterization quite well. However, the use of plasma and other surface modification techniques is well understood and practiced in automotive today. This reviewer failed to see anything that is not already used in industry and asked what the team is doing that is new. The plasma as well as the X-ray photoelectron spectroscopy (XPS) and secondary ion mass spectroscopy (SIMS) are all used to assess surfaces for bonding in industry. THE microscopic level DIC (μ DIC) is interesting.

Reviewer 4:
Progress towards the stated project milestones is good. However, Slide 22 (Remaining Challenges and Barriers) is significant; there remains a significant amount of R&D needed in this area to achieve the overall goal of increased use of CFRP/metal joints.

The reviewer expressed confusion by seemingly contradictory statements as to when the work started. Slide 2 states FY 2018 but Slide 33 (Approach) states that research began in FY 2019. A difference of one year is significant in evaluating progress towards overall project goals. Unfortunately, there is little time available in the verbal presentations to address all questions.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The team seems like it is working well together, and this appears to be a project strength.

Reviewer 2:
The project team has very clear deliverables for each lab based on structural competencies at each location. For example, surface modification at ORNL based upon prior work out of that lab.

Reviewer 3:
The collaborations between PNNL, ORNL, and material suppliers are well organized. Did the team compare the adhesives from different suppliers?

Reviewer 4:
Good coordination between PNNL and ORNL. There does seem to be a gap in deep industry participation; they are at least are not called out by individual names and contributions.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The remaining challenges and barriers attack well-known issues. Again, fundamental or practical novel contributions are unclear.

Reviewer 2:
The health monitoring and related data analysis may take a longer time than the left time. Also, health monitoring techniques are unclear, and a go/no-go plan is missing for the proposed technique if it will not work.

Reviewer 3:
Referencing Slide 23, the reviewer assumed that "Remaining Future Work" pertains to remaining work the project will attempt to complete before the project ends. However, the third bullet on the "Health monitoring of curing/manufacturing process and structural soundness in service" slide seems to be a task that is well beyond resource limits as defined in this project, which is forecasted to be completed at the end of 2020.

Reviewer 4:
The authors provided almost no insight into how outstanding issues will be addressed. How will the project team manage CTE mismatch? The team talked vaguely about using a lower modulus adhesive, but that technique is well known. The team noted that galvanic corrosion will be a concern, but how will that be addressed? How does the project team plan to isolate the components when the adhesive is poorly dispensed or when geometry allows bridging of the gap between the materials? Carbon is a very strong cathode. What is the proposed method for addressing long-term durability? How does the team ensure that things will stay bonded? What techniques will the team use to assess this? This issue prevents adhesive bonding from being more widely adopted. Undercutting of the adhesive will occur on the steel, especially if galvanic effects occur. The project team needs to do a notably better job of detailing its plan going forward. Currently, it looks like the project team has a lot of issues that will be difficult to address.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project has a strong correlation to overall DOE objectives. Adhesive bonding is the de facto solution for isolating dissimilar materials in a joint; as such, a fundamental understanding of the interface between the substrates and adhesive is critical.

Reviewer 2:
Using adhesives is of clear practical importance for next-generation vehicles. This program squarely addresses those issues.

Reviewer 3:
This project meets DOE objectives by reducing structural weight.

Reviewer 4:
Yes, trying to bond CFRP to steel is worthy to research. However, the reviewer did not see much of a chance that this project would contribute toward this goal as it is currently structured. Surface modification is the

easiest and best understood part of that puzzle. The rest is difficult, and the team may not have the right expertise to do so.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources are sufficient with regards to the milestones defined on Slide 4.

Reviewer 2:
The project team seems like it is using its resources well.

Reviewer 3:
The team is well prepared with the resources for the proposed work.

Reviewer 4:
This is a solid program that addresses well-known needs in next-generation automotive design and manufacture. A clear case is not made of exactly how this program fills technical gaps in literature, industrial practice, or knowledge.

Presentation Number: mat138
Presentation Title: Solid-State Joining of Magnesium Sheet to High-Strength Steel
Principal Investigator: Piyush Upadhyay (Pacific Northwest National Laboratory)

Presenter

Piyush Upadhyay, Pacific Northwest National Laboratory; Zhili Fang, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

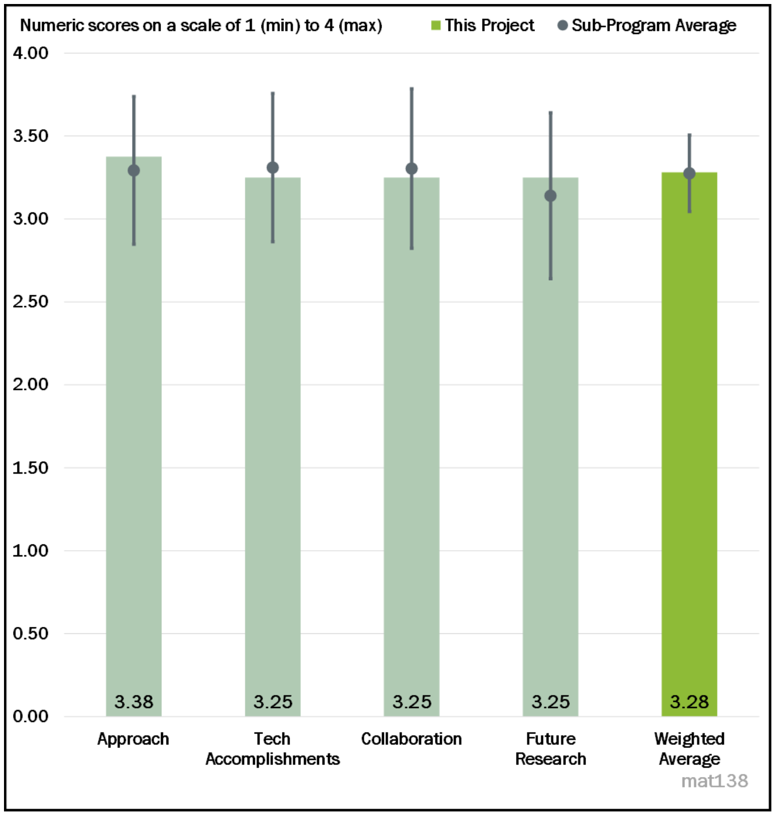

Figure 6-9 - Presentation Number: mat138 Presentation Title: Solid-State Joining of Magnesium Sheet to High-Strength Steel Principal Investigator: Piyush Upadhyay (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This plan represents an excellent coupling of outstanding, important, practical issues of joining advanced metals, novel solid-state processes, advanced structure characterization, and thoughtful mechanical testing—well done.

Reviewer 2:

The project hypothesis is that the joining mechanism is dependent on observations of different elements at the interface and the project team has focused project activities accordingly. The typical process parameters and inherent variability has been acknowledged, but is not the focus of this work, rightly. The application of two, solid-state joining technologies as discussed on Slide 4 provide unique paths to investigate the interface, which is well designed.

Reviewer 3:

The approach is to control the chemistry of the interface to maximize performance of Mg-steel joints.

Reviewer 4:

It seems that the transmission electron microscopy (TEM) function is not fully utilized in identifying structures formed at the bonding interface; only the elemental distributions were presented.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Current results reveal complicated interfacial structures formed at the bonding interface; more in-depth analysis is needed to fully understand the bonding mechanism. The modeling of welding processes provides important information, such as temperature and pressure, which could be further applied in analysis of the generated structures or prediction of the structures with a multiscale modeling approach.

There are eight publications/presentations from this project, which is impressive.

Reviewer 2:
A stated goal is to understand interface chemistry and properties to tailor the joint interface. The project has applied analytical techniques and, in the case of the atom probe tomography, developed a unique approach to understand the interface chemistry and structure. Subsequently, the project has achieved excellent progress. Regarding tailoring the joint interface, the project has achieved a fundamental understanding that enables the team to now address this issue. It is doubtful that the team will be able to make significant impact in this area given the relatively short period remaining in the project.

Reviewer 3:
Important results are being developed in process development, microstructure characterization, and strength testing. Results are all credible and use state-of-the-art techniques. It would be good to cite publications and presentations.

Reviewer 4:
The reviewer observed good progress this cycle, although the issues surrounding bare steel are problematic.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The work planning—ultrasonic welding (USW) at ORNL and friction stir welding (FSW) at PNNL—plays to the strengths of each lab, and characterization and focus on fundamental understanding of the interface drives the two teams to collaborate. This is a very smart approach and enables good collaboration on a common challenge.

Reviewer 2:
The project has a large and well-coordinated team.

Reviewer 3:
The team is strong as part of the broader interface by design effort.

Reviewer 4:
The collaborations were not clearly addressed in the presentation, such as how the two teams from ORNL and PNNL collaborate on different tasks.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
Plans to investigate joining mechanisms in these difficult materials, effect of loading, and post-weld thermal exposure are all important issues with a clear plan.

Reviewer 2:
Future work aligns well with the project scope. The only concern is if the team has enough time to finish the proposed work, especially during COVID-19.

Reviewer 3:
The four main bullets called out on Slide 16 are appropriate near-term issues that the project should address. However, these items cannot be adequately addressed in the remaining time or with the current level of resources. The reviewer commented that these bulleted items should spawn new projects themselves. For example, the question of resonance is a good one for high performance computing (HPC) if USW is applied to a sub-assembly or other large vehicle structure given the computational needs for that problem statement. The effect of post-weld heat treatment (i.e. paint bake effect) is a very interesting problem looking at aging/residual stress/CTE effects, especially for dissimilar metal joints.

Reviewer 4:
It is unclear how future work will lead to successful bare steel joints.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project supports DOE objectives.

Reviewer 2:
This project clearly addresses issues relevant for dissimilar metal joining, which supports the overall strategy of the right material, in the right form, and in the right application for optimum mass savings potential.

Reviewer 3:
It is essential to understand how advanced and dissimilar metals can be joined. This provides important guidance.

Reviewer 4:
This project supports lightweighting technologies by joining dissimilar lightweight materials.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The team is well prepared with the resources for the proposed work.

Reviewer 2:
Project resources should be sufficient to achieve the second milestone listed on Slide 3 by year end.

Reviewer 3:
These are difficult, advanced experiments, and the budget looks appropriate.

Reviewer 4:
Sufficient resources have been allocated to perform the work.

Presentation Number: mat139
Presentation Title: Mechanical Joining of Thermoplastic Carbon-Fiber Reinforced Polymer to Die-Cast Magnesium
Principal Investigator: Keerti Kappagantula (Pacific Northwest National Laboratory)

Presenter

Keerti Kappagantula, Pacific Northwest National Laboratory; Yong Chae Lim, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

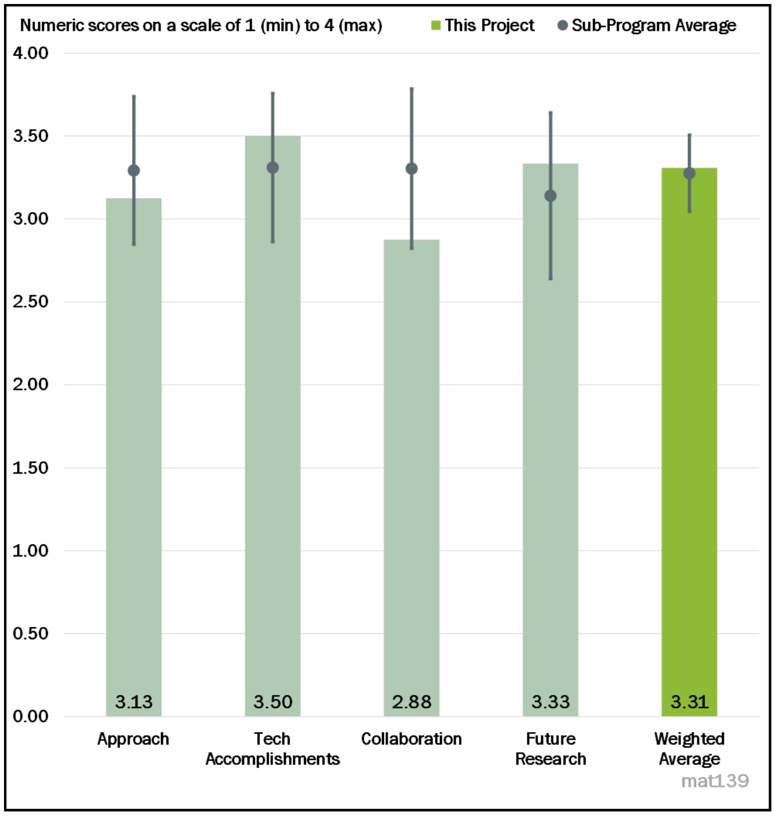

Figure 6-10 - Presentation Number: mat139 Presentation Title: Mechanical Joining of Thermoplastic Carbon-Fiber Reinforced Polymer to Die-Cast Magnesium Principal Investigator: Keerti Kappagantula (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project is comprehensive in that it covers process, mechanical and corrosion properties, and has many innovations in joining methods. There is good justification for the methods chosen and they are in line with the state of the art. A slightly broader scope would have been welcomed by this reviewer. Although plan design is useful and consistent with the budget, the covered scope may be a little too broad for the budget. The reviewer asserted that work addresses clearly important areas.

Reviewer 2:

Technical approaches are well planned to achieve the milestones. However, the corrosion mechanisms were not explained; only the effect of corrosion on mechanical strength and failure modes were presented.

Reviewer 3:

The project goal is to develop new Mg/CFRP joining technologies with corrosion performance improved above baseline solutions. Subsequently, the project has taken nascent technologies—friction stir interlocking and friction self-piercing riveting—and applied them to Mg/CFRP joints and evaluated resulting joints with respect to corrosion. This project is higher on the technology readiness level (TRL) and has a corresponding approach compared to some of the other joining core programs. However, the common approach for dissimilar material joints is to apply adhesive at the joint interface and including this variable would have improved comparison of this work to current solutions.

Reviewer 4:
This reviewer noted that the approach did not include a high-volume joining method and added that pop rivet and Teflon-taped fasteners are great control baseline methods.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Excellent results in terms of quality and quantity were observed by this reviewer. Good innovation has been shown in redesign of the spot joining process and corrosion.

Reviewer 2:
The project has developed satisfactory joint strengths using a range of solutions and addressed the fundamental issue of galvanic corrosion with each of the three methods.

Reviewer 3:
The project plan was executed by PNNL and ORNL as designed.

Reviewer 4:
Significant testing has been done, and more in-depth analysis is needed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer indicated that it is clear the group meets regularly and is well coordinated across both labs and with BASF in the loop.

Reviewer 2:
Each lab leveraged its unique capabilities to develop the joining technologies while the common challenge of Mg/CFRP galvanic corrosion united the team. There appears to be satisfactory collaboration with this project.

Reviewer 3:
Two National Laboratories lead the two tasks based on two joining technologies. It was unclear to this reviewer how these two tasks/teams interact, as well as how knowledge gained from one process can help the other process.

Reviewer 4:
Very little, if any, collaboration took place between ORNL and PNNL. Each group took a different approach and proceeded without interaction and collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
Proposed issues related to friction stir Interlocking and bolting are useful and well justified.

Reviewer 2:
Future work focuses on testing to which the reviewer suggested including more in-depth analysis. Additionally, the technology transfer from lab to industry is unclear.

Reviewer 3:
The tasks as outlined in Slide 18 are appropriate items to be addressed. The reviewer questioned whether sufficient resources remain to adequately address these issues by the forecasted project completion of year-end 2020.

Reviewer 4:
The project has been completed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project supports a technology gap identified by DOE. Multi-material joining continues to be an enabler for lightweight material use, resulting in fuel reduction and increased energy efficiency associated with electrified vehicles and transportation systems.

Reviewer 2:
This project squarely fits into supporting the overall DOE objective of reduced GHG emissions via increased use of lightweight materials as part of a mixed material strategy.

Reviewer 3:
This project supports lightweighting technologies by joining dissimilar lightweight materials.

Reviewer 4:
Joining ultralight materials is a clear problem with needed innovation, which this project addresses.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources were sufficient and matched the funding level.

Reviewer 2:
The team is well prepared with the resources for the proposed work.

Reviewer 3:
Resources are justified, but there is a wide scope.

Reviewer 4:
Although the project has made significant advances with available resources, it is questionable whether sufficient project resources remain to adequately address issues by the forecasted project completion of year-end 2020.

Presentation Number: mat142
Presentation Title: Metal-Matrix Composite Brakes Using Titanium Diboride
Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory)

Presenter

Glenn Grant, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

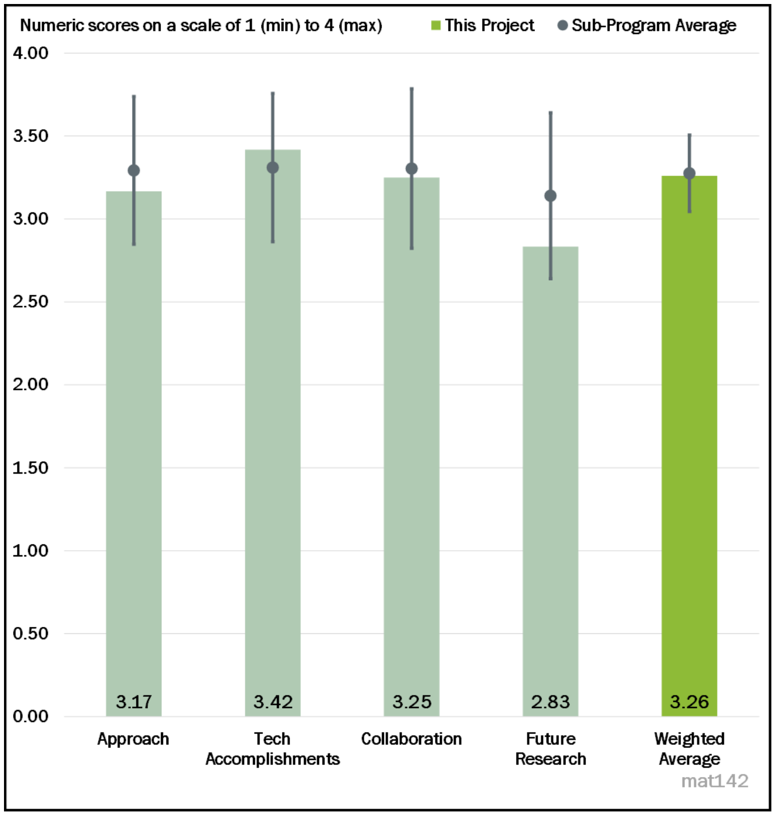

Figure 6-11 - Presentation Number: mat142 Presentation Title: Metal-Matrix Composite Brakes Using Titanium Diboride Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The technical approach for using metal matrix composites (MMC) such as titanium boride (TiB_2) and aluminum in various compositions is sound and a good approach for significantly reducing the weight of brake rotors while increasing braking performance. The project was well designed to produce the master alloy and casting alloy to compare to various compositions of metal matrix materials using high-speed techniques to mix the two major components. The reviewer noted a well-conceived approach for using microscopic characterization of the materials for particle homogeneity and porosity before subjecting test samples to industry standard wear tests to characterize the brake rotor component. Cost barriers identified in the overview were not addressed during this project phase. The intent is to do a cost analysis when an OEM partner evaluates the MMC rotors in a full assembly environment.

Reviewer 2:

This reviewer observed a technically-sound approach for making aluminum MMC (with various TiB_2 volume fraction reinforcement) brake rotors replacing cast iron-based rotors. There are challenges associated with aluminum-based MMCs in extreme braking conditions and the authors are aware of that. In addition to lightweighting, there are other benefits such as reduced particulate matter pollution with the Al-MMC based rotors.

Reviewer 3:
Very clear layout of basic approach to fabricate samples was noted by the reviewer. The casting process results show fairly homogenous mixing on the metal matrix and composite. It would be interesting to see more machinability data because this task is required to fabricate the test samples. It is assumed that the casting process is more expensive than cast iron, and the reviewer expected the same to be true for machining. Are these increased costs completely offset by the improved wear life?

In the project team approach, rotors were fabricated from cast plates. Can rotors made from this material with the PNNL casting process be cast near net shape to improve costs by reducing machining?

Excellent details on the review of wear testing, the selected method, and the specific testing profiles.

Will the testing include some severe stopping conditions to evaluate if the rotor can survive or would need replacement after such an event, or worse case fail?

Reviewer 4:
The project's technical approach is adequate for a screening study on the possibility of using TiB_2-Al brake rotors. However, without a technical cost model and analysis of the best potential solution, there can be nothing claimed about addressing the three stated cost barriers to MMC rotors.

Reviewer 5:
The three major barriers listed in this project are all related to the cost (raw material, cost of production). However, these major barriers do not seem to be directly addressed by the proposed effort given that reduced weight and improved performance can also save on vehicle cost.

Reviewer 6:
A simple task was noted by this reviewer; no new technical expertise is being developed. The reviewer commented that a newer material is being used in an older, proven technology of squeeze casting. Validation of this material using common tests is not highly groundbreaking.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The technical accomplishments and progress have been outstanding given the level of funding and collaboration between the technical performer and the material producer. The melt trials produced machinable test rotors with very good distribution for the TiB_2 particles within the composite material. Improvements to the brake test stand will ensure better results that will be closer to the technical standard test procedures. The test methodology was well defined and followed typical industry test standards. The parameters for each phase of the test method were well defined and adequate for obtaining the necessary data to screen the test rotors. Test samples were well chosen to compare to baseline test materials and to actual OEM brake rotor configurations. Using a dynamometer test method is more realistic for obtaining results similar to an actual operational environment. This project phase is ending, and the results presented showed very good progress and results that met performance indicators for each of the tasks on the project schedule Gantt chart.

Reviewer 2:
The project team has made excellent progress towards its project goals.

Reviewer 3:
Excellent technical progress on the test stand and test planning. Production of the test samples for the brake wear test is complete for three TiB_2 loadings, and the pads are identified and presumably obtained.

Reviewer 4:
The project is well managed with successfully completed tasks at both industry and DOE lab. Expertise in both organizations has been utilized with good outcome, and minimal challenges have been encountered.

Reviewer 5:
The project seems to show developed MMC material has good performance. It would be better to show a comparison of the developed material with conventional material (e.g., cast iron, other MMC material like silicon carbide [SiC]), in various areas.

It is unclear what type of material characterization was done to correlate the performance with the microstructure of the material. Does the distribution of TiB particle affect the performance?

Reviewer 6:
The reviewer indicated a significant amount of testing and characterization of the tested samples that need to be completed over the next quarter. Hopefully, there is sufficient time to extract all useful information from these tests and make appropriate conclusions. Additionally, the reviewer did not get a sense that this wear testing was being conducted throughout 2019 as the schedule indicated.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This reviewer commented that the National Laboratory and industry partner are a good match.

Reviewer 2:
Appears that this project is mainly a PNNL effort outside of the original material procurement. Society of Automotive Engineers (SAE) standards are being closely followed for wear testing and PNNL appears to have all necessary capabilities.

Reviewer 3:
The collaboration is between a DOE National Laboratory and a supplier of raw materials to vehicle manufacturers. The coordination is excellent for producing the baseline test samples and the prototype test samples that compare to OEM component parts. Tasks are appropriately divided for raw material production, casting/machining/testing of rotor samples, and material characterization. There was no indication of direct involvement by an OEM in this project phase. The presenter stated that this phase is for “screening” the new MMC rotors and an OEM is anticipated to be involved in future efforts.

Reviewer 4:
Only two partners and few suppliers of services were reported by this reviewer, who also noted a well-managed project in which expertise was available from the partners for project completion.

Reviewer 5:
Clean approach to division of tasks between the partners.

Reviewer 6:
Arconic and PNNL collaborated on this effort.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
Very good plan in place to conduct wear testing of the samples to compare performance with different TiB_2 levels and pad materials.

Reviewer 2:
Good project close out is expected given the progress to date.

Reviewer 3:
Proposed future research focuses more on performance evaluation. Additional effort to utilize advanced material characterization techniques and correlate microstructure of material with its performance is key to better understanding this class of material for future improvement.

Reviewer 4:
Proposed future research involves completing the prototype rotors and tribologic characterization of the friction pairs for optimization. The remaining task includes determining the specific wear rate of the rotor materials. This is a logical approach for finishing Phase 1. The presenter did not describe decision points, risks, or risk mitigation for project completion. However, the project is scheduled to be completed within four months; so, it is somewhat late to be considering risks at this point. Success of the research effort is based strictly on past performance.

Reviewer 5:
This reviewer noted the end of the project and no new proposal for future work. The reviewer also highlighted no plan to commercialize the end product.

Reviewer 6:
The proposed future work focuses on technical performance of the rotors. However, the three barriers that all speak about costs are not identified. This reviewer had hoped to see a technical cost model for the manufacturing, machining, and vehicle use stage of the lightweight rotors.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The relevance of this project is a significant weight reduction (greater than 50%) of a vehicle component as compared to the DOE 20% goal. If successfully incorporated in a new vehicle by an OEM, the weight savings could also result in a moderate fuel saving, which is also a DOE objective. The presenter also identified an additional environmental impact that is not a stated goal of DOE.

Reviewer 2:
The project supports DOE's lightweighting objective along with reduced particulate matter emissions.

Reviewer 3:
Brake research is clearly relevant to vehicle technology.

Reviewer 4:
Looking at the evolution of transportation systems, materials technologies is at the heart and is a key enabler for all technologies on the horizon.

Reviewer 5:
Braking can be effectively used for regeneration and more stable product will help achieve this goal. Energy conservation will play a role in fuel efficiency and GHG reduction.

Reviewer 6:
Reducing rotating mass has a compounded benefit for fuel economy. It reduces both overall mass that must be moved and the rotational inertia to get the wheels rolling and stopping.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources are okay for the proposed performance evaluation, but additional resources may be needed for structure characterization.

Reviewer 2:
Resources are sufficient for the level of effort described. The industry cost share was typically significantly more than other DOE-funded research projects, which demonstrates a significant investment and high level of interest by industry for the end product.

Reviewer 3:
Sufficient resources were noted by this reviewer.

Reviewer 4:
Resources are sufficient and project is nearing its end.

Reviewer 5:
Project budget appears sufficient as no flags raised and project is near completion. The reviewer did recall a breakdown of remaining funds.

Reviewer 6:
This reviewer noted the last stage of the project.

Presentation Number: mat146
Presentation Title: Ultra-Lightweight, Ductile Carbon-Fiber Reinforced Composites
Principal Investigator: Vlastimil Kunc (Oak Ridge National Laboratory)

Presenter

Vlastimil Kunc, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

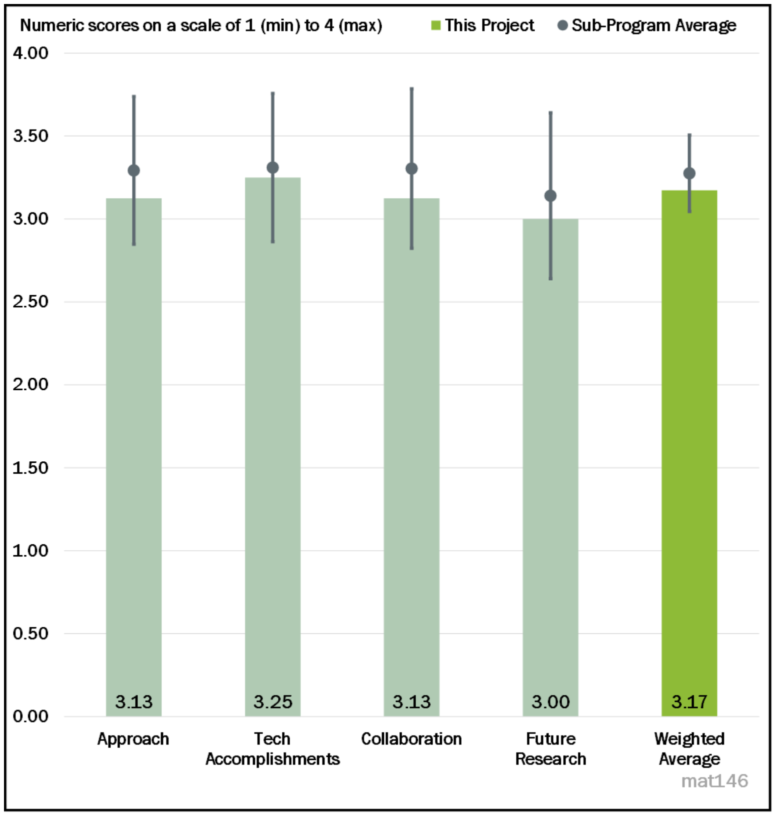

Figure 6-12 - Presentation Number: mat146 Presentation Title: Ultra-Lightweight, Ductile Carbon-Fiber Reinforced Composites Principal Investigator: Vlastimil Kunc (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Good approach for this initial study to quantify opportunities and identify challenges.

Reviewer 2:

Using three-dimensional (3-D) printing to manufacture functional material is great approach. Creation of lightweight, high-stiffness microlattice with good damping properties will enable applications of carbon fiber composite in certain special area.

Reviewer 3:

The Research team has pursued a broad range of structural configurations through novel 3-D additive methods and materials. The innovative work is impressive, but the research team could do a better job of spelling out its approach to the research—step 1, step 2, etc. The project team is more intent on showing results and the work performed than describing the starting point, intermediate steps, and the final objective with stated goals. The stated "Overall Objective" does not contain any specifics related to strength, stiffness, deposition rate, or cost goals. It makes it difficult to assess the progress or viability of the technology.

Reviewer 4:

The approach for executing the work seems to be adequate. The reviewer was uncertain about how exhaustive the search was for an optimum, cellular micro-lattice geometry. A more detailed rendering of how this was achieved would be helpful. Perhaps this was presented in prior year(s)?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project used a multi-material projection microstereolithography (PμSL) system to have successfully printed lightweight cellular test specimens and dementated the printed material's improved damping properties. The impact of density with different amounts of soft phase and size effects of the lattice are also explored.

Reviewer 2:
The work accomplished and progress reported is very impressive. Material fabrication and characterization is complete and shows novel properties compared to conventional materials and methods. This is very well done. The reviewer had only one reservation related to relevance that can only be assessed in the context of cost and scalability, which is not adequately addressed here.

Reviewer 3:
The current technical accomplishments presented go a long way in elucidating intrinsic and structural dampening effects. More needs to be presented on the printing parameters used in manufacturing the lattice structures. The projected economic viability/feasibility (techno-economic analyses) of this method of manufacturing lattice structures for, and in, usable components needs to be addressed.

Reviewer 4:
Good technical progress on the printing and testing. It is not clear how much work was accomplished in this year. How many samples were produced and tested?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Good collaboration though the division of labor and roles and responsibilities are not clearly defined in this presentation.

Reviewer 2:
Given the work accomplished, there can be no doubt that the team has worked effectively. The presentation and reporting do not clearly show the contribution of both partners; however, the work content demonstrates effective program execution.

Reviewer 3:
The project seems to be completed by the PI's team.

Reviewer 4:
There are only two partners in this project. Collaboration seems to be adequate. However, it was mentioned that the Principal Investigator (PI) at Virginia Polytechnic and State University (VT) recently moved to University of California, Los Angeles (UCLA). The presenter did not address whether the move will delay or even impede the work. Did the project move with the Co-PI (Dr. Zheng) to UCLA?

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
Good next steps to identify opportunities and challenges.

Reviewer 2:
The planned research covers a number of new techniques and areas. The reviewer would like to see more comprehensive studies of the new material, especially, their structural strength and durability. Cost assessment of the technology also needs to be considered.

Reviewer 3:
The projected economic viability/feasibility (techno-economic analyses) of this method of developing lattice structures for, and in, production of usable parts/components needs to be addressed.

Reviewer 4:
The proposed research addresses (to some extent) the need to extend scale to "large area CFRP .", which is an important step to create pragmatic materials for structural applications. However, the proposed scale of "> 25 cm x 25 cm" is somewhat underwhelming. Lacking specific reference to build rates, it is difficult to assess the value. Modern automotive operations manufacture full systems at a rate approach one per minute (or faster), it is important to recognize both scale and throughput are critical parameters. Clearly, the future work is pointed at extending material capability, this reviewer remains concerned whether expanding capability is as important as extending scale and rate.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
If this technology is successfully developed, it will greatly improve the strength of carbon fiber structures. This will promote more extensive use of CF for many structures in vehicles.

Reviewer 2:
The use of 3-D printing technologies to create new material forms (hybrids with novel architectures at small scale) can reveal (at large scale) new material performance that is counter intuitive (e.g., high stiffness with high dampening). This fundamental research is an important building block for development of future systems that will exploit this novel materials approach. To the extent that the methods revealed by this program are scalable to support vehicle manufacturing, the combination of high specific properties and desirable ductility and damping characteristics are important goals of the DOE for lightweighting of vehicle systems.

Reviewer 3:
Carbon fiber composite with improved damping and other properties will enable wider usage of carbon fiber composite and lead to light weight of vehicles.

Reviewer 4:
Tailored materials should reduce vehicle weight and improve performance.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project goes well and is achieving its objectives.

Reviewer 2:
Sufficient funding and resources for this early work.

Reviewer 3:
This team has created significant value in terms of results for the overall program cost. This is notable and commended by this reviewer. Good work with novel outcomes. Please address the feasibility of scaling and address the technology gaps that exist so we can better assess the future funding needs to apply this work in real applications.

Reviewer 4:

This reviewer assumed the budget was sufficient. Authors did not present enough information to ascertain that this was the case. The little information presented might suggest that funding will not be adequate. Total budget seems to be about $1,000,000. Project duration as stated by the author is 50 months (October 2018 to December 2022). 40% of the work has been done, but the amount of money spent was not stated. However, a full 46% of the budget is slated to be spent in FY 2020.

Presentation Number: mat147
Presentation Title: Continuous-Fiber, Malleable Thermoset Composites with Sub-1-Minute Dwell Times: Validation of Impact Performance and Evaluation of the Efficacy of the Compression Forming Process
Principal Investigator: Philip Taynton (Mallinda, Inc.)

Presenter

Philip Taynton, Mallinda, Inc.

Reviewer Sample Size

A total of zero reviewers evaluated this project.

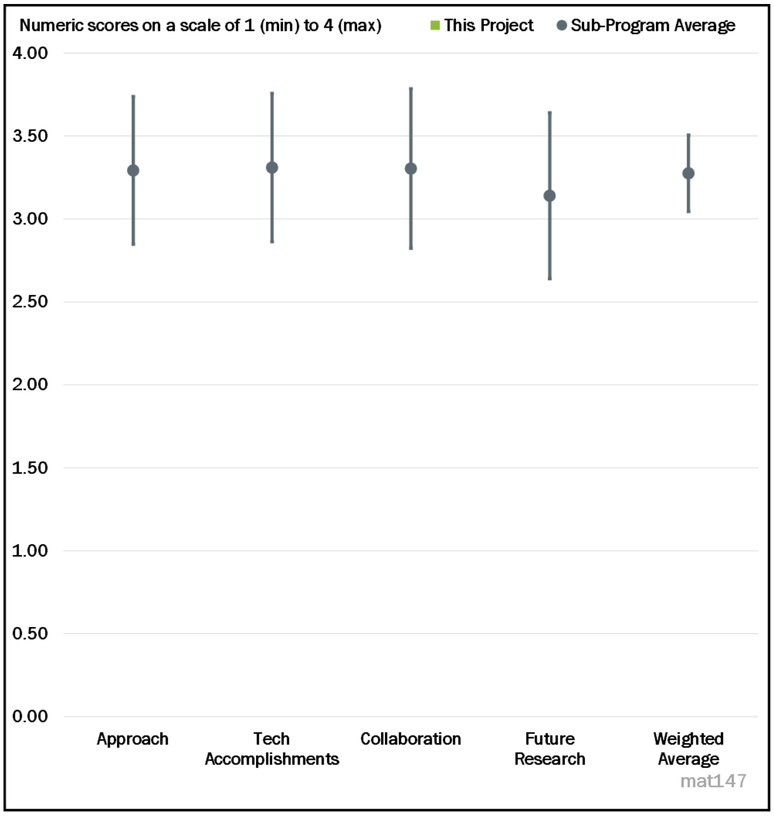

Figure 6-13 - Presentation Number: mat147 Presentation Title: Continuous-Fiber, Malleable Thermoset Composites with Sub-1-Minute Dwell Times: Validation of Impact Performance and Evaluation of the Efficacy of the Compression Forming Process Principal

Project Relevance and Resources

No responses were received in this section.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

No responses were received in this section.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

No responses were received in this section.

Question 3: Collaboration and Coordination Across Project Team.

No responses were received in this section.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

No responses were received in this section.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

No responses were received in this section.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

No responses were received in this section.

Presentation Number: mat149
Presentation Title: Non-Rare Earth Magnesium Bumper Beams
Principal Investigator: Scott Whalen (Pacific Northwest National Laboratory)

Presenter

Scott Whalen, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

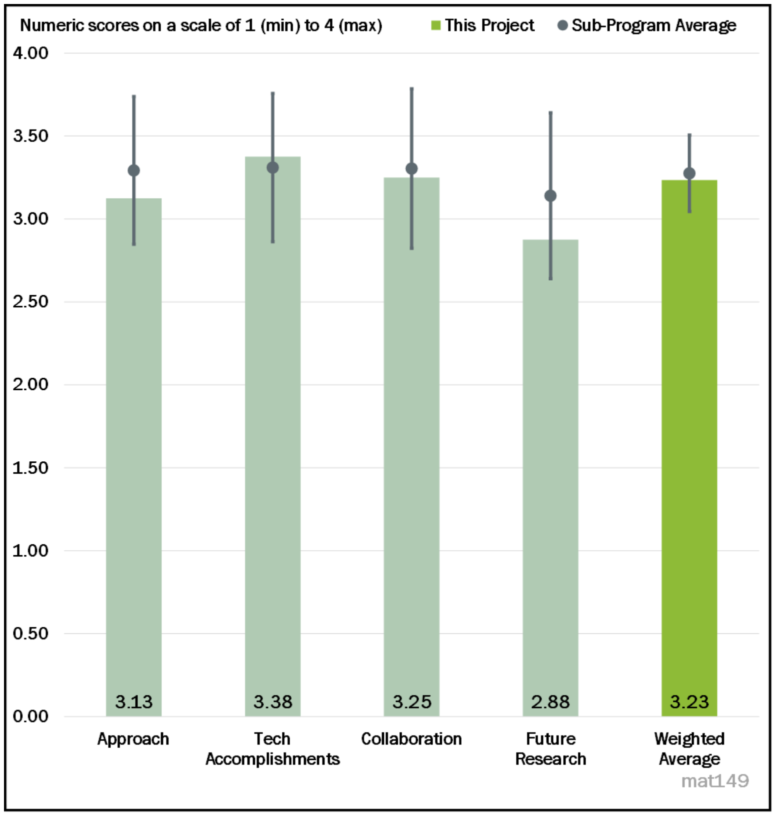

Figure 6-14 - Presentation Number: mat149 Presentation Title: Non-Rare Earth Magnesium Bumper Beams Principal Investigator: Scott Whalen (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project addressed fabrication and evaluation of A6063 alloy extrusions using shear assisted processing and extrusion (ShAPE). This is a project with a modified objective from last year; the aluminum task is added and made as first priority. Additionally, the reviewer reported the following experiments: using virgin feedstock followed by recycled scrap; moving from solid to hollow cylinders and then non-circular shapes, which is very progressive; and using magnesium alloy. This will give enough information on the process viability.

Reviewer 2:

The project applies ShAPE processing developed at PNNL to fabricate non-RW Mg alloy bumper beams. The scope has been modified to include extrusion of Aluminum scrap to make ductile Al alloys in the 6xxx family. The approach in this effort is reasonable in all aspects.

Reviewer 3:

The project approach contributes to overcoming most barriers related to producing non-rare earth Mg bumper beams and does so in a logical progression. This includes the addition in June 2019 of more commercially available and readily extrudable AA6063 to increase commercial interest and prove the process before proceeding to the more difficult ZK60 extrusion. However, the project focus is lacking slightly in the omission of typical Al bumper alloys such as AA6061, 6083, or 7xxx alloy. While this project has achieved T6 properties from a T5 heat treatment, those properties are still substantially lower than a conventional higher strength bumper beam grade alloy. There may also be a significant risk to the program in shifting from circular AA6063 extrusions to non-circular ZK60 extrusions without investigating non-circular AA6063 before ZK60.

Reviewer 4:
The approach steadily builds on successively more difficult technical barriers to prove the process at this pilot scale. However, there is no technical cost modeling to build a business case for a successful result.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The milestones have been reached and technical accomplishments towards overall project goals are good.

Reviewer 2:
The tooling improvements have been excellent! Great results. This reviewer had hoped to see the quantities and "run at rate" information to assess if this was a lab or prototype scale accomplishment.

Reviewer 3:
Technical accomplishments so far seem to be very well aligned with supporting the stated project approach. This reviewer highlighted very good results on AA6063 properties and excellent improvement in surface results, extrusion force, and motor torque from modified tooling, although the machine limitations prevent the ability to evaluate the process at commercially acceptable extrusion rates. The presenter suggested that wide data spread on elongation results may be explained by gripping issues in test cell. Additional testing should be conducted to verify if this is the case. It will be worthwhile in future work to evaluate dimensional accuracy and consistency of extrusion profiles, especially on non-circular profiles.

Reviewer 4:
The project team completed the extrusion of a virgin alloy. Although the selection of 6063 is not justified because it is not normally used for auto applications, 6061 is). Also, this operation may be slower than existing operation. Advantages need to be clarified.

The claim of improved T5 properties needs to be qualified. When extruded from 450C, it could have undergone a quench operation when exiting the punch, thus making it more or less a T4 condition. Subsequent T5 made it close to T6. The reviewer asserted that micro studies are needed to confirm the improved properties; and wide scatter in the properties, including yield strength (YS), needs to be evaluated. Normally, YS will not show much difference with micro defects.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This reviewer observed excellent collaboration to produce these results.

Reviewer 2:
This is a LightMat project with collaboration with Magma. Excellent collaboration with the industry partner is noted.

Reviewer 3:
Only a tier one supplier is involved; partner contribution is significant with help on design and fabrication of tools.

Reviewer 4:
Well-coordinated collaboration that seems to utilize the complementary strengths of the lab and industry partner efficiently. While there are only two collaborators working on the project, these two should be

sufficient for the near term, although ultimately, adding a commercial extruder could help expedite process commercialization.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The project is on track to meet the (modified) goals that have been set forth.

Reviewer 2:
While the overall approach is good, the evaluation of AA6063 in a non-circular profile would seem to be a logical addition to the plan prior to going straight to non-circular profile ZK60, which is more difficult to extrude than the AA6063. Additionally, modification of tooling (if feasible) to accommodate higher extrusion rates and addition of a commercial extruder would help increase likelihood of using the process in production.

Reviewer 3:
Work on 6063 with scrap as an input is continuing. However, this is more of a commercial application than automotive. The trial may provide technical information, but an alloy relevant to auto needs to be selected.

Reviewer 4:
The proposed future work will lead to a "proof-of-concept" technical assessment. Including a technical cost model would strengthen the project.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project supports DOE objectives by focusing efforts at developing a process to produce high strength lightweight Mg alloy bumper beams (and potentially other extruded structural components) cost effectively. While also evaluating the new ShAPE extrusion process on more readily available and lower cost AA6063 to meet the industry partners nearer term needs.

Reviewer 2:
Cost reduction in wrought light alloys is an enabler for wider use in vehicles. This will in turn help more light weighting.

Reviewer 3:
Project supports lightweighting goals through the development of non-RE Mg alloys and aluminum alloy extrusions from scrap.

Reviewer 4:
Aluminum and magnesium performance as well as the likely costs of producing linear profiles would probably reduce vehicle mass and, therefore, improve fuel economy.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project budget seems appropriate for the length and complexity of the program. The project has already progressed to the point of producing improved quality, non-circular, thin-wall AA6063 extrusions while using approximately 50% of the budget. Subsequently, it would appear that another 50% of the budget should be sufficient to finish the project and hopefully, to accommodate any surprise issues that arise.

Reviewer 2:
Sufficient resources were noted by the reviewer.

Reviewer 3:
Resources are sufficient.

Reviewer 4:
No comments were indicated by this reviewer.

Presentation Number: mat151
Presentation Title: Phase-Field Modeling of Corrosion for Design of Next-Generation Magnesium-Aluminum Vehicle Joints
Principal Investigator: Adam Powell (Worcester Polytechnic Institute)

Presenter

Adam Powell, Worcester Polytechnic Institute

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

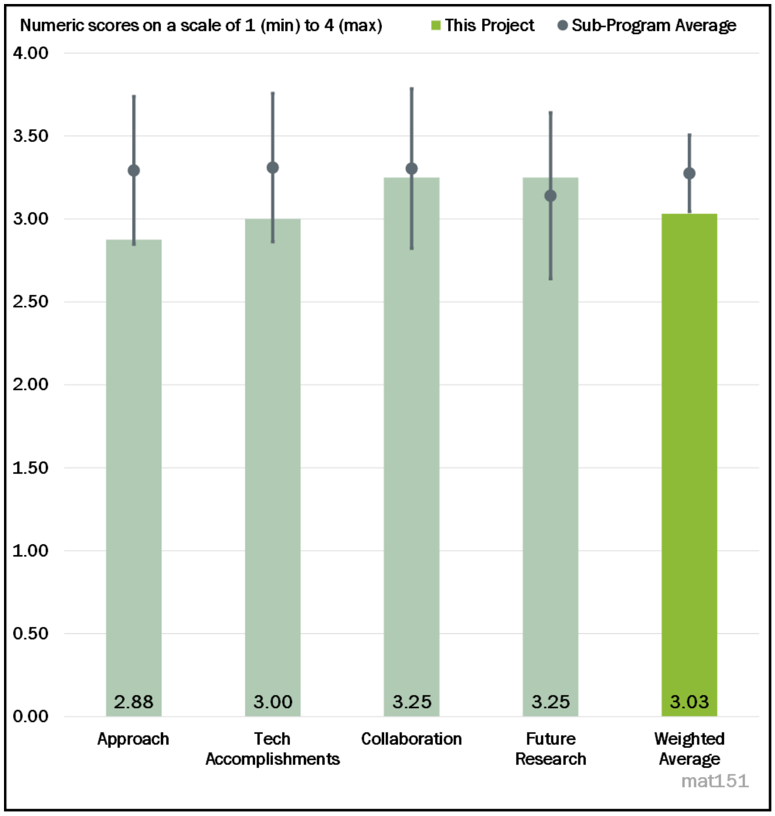

Figure 6-15 - Presentation Number: mat151 Presentation Title: Phase-Field Modeling of Corrosion for Design of Next-Generation Magnesium-Aluminum Vehicle Joints Principal Investigator: Adam Powell (Worcester Polytechnic Institute)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The technical approach of developing and validating a model of microgalvanic corrosion and mechanical failure based on joint microstructure is well-designed and feasible. It also addresses a critical need in providing enhanced understanding and prediction of multi-material joint corrosion and fracture.

Reviewer 2:

Overall approach appears sound. Using Mg/Al diffusion couple to validate the diffusion model is a good idea. However, it was unclear to the reviewer how the corrosion model referenced on Slide 13 has been validated for the Ti-Mg-Cl system. The reviewer saw plots of simulation results but did not see how this is validated against experimental measurements.

Additionally, this reviewer asked the following questions:

- How will the phase field modeling address the difference in grain size between the stir zone and base materials? It is known that the refined friction stir zone will have a lower corrosion rate.
- Will the team address the difference in strengths between the friction stir weld and base material as crack propagation typically follows along this interface?

Reviewer 3:
The effect of the identified intermetallic compounds on corrosion and fracture have not been adequately addressed. The reviewer presumed this will be addressed in the future as part of this work.

The reviewer found the model described on Slide 14 to be rather simplistic. The reviewer assumed that this is an initial simplified model. The model as is does not take into account the compositional and metallurgical variability across the fusion line and into the pure material on both sides of the fusion line. Is FSW being used as a surrogate for diffusion bonding? If so, variability also occurs in diffusion bonding, and the previous comment about compositional and metallurgical variability across the weld fusion line and adjacent metal would still apply.

Reviewer 4:
Overall, the approach seems logical but is not defined well enough to ascertain how well it is addressing the technical barriers. Tasks are unclearly defined and metrics for evaluating corrosion at joints are not well defined either.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The team has accomplished good progress towards achieving its ultimate goals given a roughly 1/3 burn rate by validating the model based upon Mg/Al diffusion joints with clear microscopic analysis which has been modeled with good correlation (Slide 9). It is clear that the project should continue with the triangular friction stir weld tool.

Reviewer 2:
The reviewer observed good progress made. There is still limited understanding per the data presented about what the effect of the intermetallic compounds is on corrosion and degradation. Additionally, the corrosion model still requires some work.

Reviewer 3:
The technical accomplishments to date are encouraging and generally on-time. The two-dimensional (2-D) model is still limited to simple Al-Mg-H2O ternary system and must be expanded to the Mg-Al-H-O quaternary system to address corrosion product formation.

With the understanding that there was a limited amount of time to present a large body of work, it was hard to dig into technical details. It was interesting to see that the final voltage min/max are located near the edge of the 2-D simulation on Slide 14. Does the position of the min/max voltage change with time (or simulation cell size); if so, how?

Reviewer 4:
Technical accomplishments seem to support the stated approach for the most part. However, a go/no-go for Budget Period 1 was to predict corrosion pit depth within +/- 2X while nothing in the “accomplishments and progress” section of the report even mentions pit depth with respect to testing or prediction. Furthermore, there does not seem to be anything in the presentation comparing predicted corrosion results to test results.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Slide 4 provides an excellent overview of the various tasks, timing, and which partner is delivering what. It is clearly based upon each partner’s competency and the work to date clearly highlights the collaboration between partners without which they would not be able to achieve the results presented here.

Reviewer 2:
Collaboration within the team seem to be good and effective.

Reviewer 3:
Collaboration among partners seems to be well instituted and effective.

Reviewer 4:
Overall, it appears that collaborative partners have complementary strengths. However, their roles are not defined as clearly as they should be. For example, PNNL is responsible for Task 1, but Task 4 is not defined anywhere in the presentation.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The proposed future work and associated deliverables are appropriate for the program.

Reviewer 2:
The project presents a well-thought approach to the problems of corrosion at this point. There is a path forward that has been identified and the tasks outlined in Slide 4 support this path. One concern the reviewer had was the potential for the difference in microstructure/properties of the stir zone versus base materials to affect not only the assumed corrosion rates, but also the strength/fracture of the joints.

Reviewer 3:
This reviewer remarked that there was no mention of elucidation of effect of intermetallic compounds on corrosion and degradation. Additionally, there was no mention of any testing to better understand materials fracture. It appears fracture is going to be modeled without gathering of test data. If so, this is not ideal.

It would have been nice to better understand the effect of the weld microstructure and chemical variability on corrosion and fracture, and how these may be represented in the final model. Do the authors consider this to be part of the scope of this work?

Reviewer 4:
Although details are lacking, future work seems well planned to support the project objectives. Metrics seem to be lacking for determining the capability of the model to predict physical corrosion.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This program addresses multi-material joint corrosion and fracture, which are critical parts of implementing multi-material systems.

Reviewer 2:
The project supports the DOE objectives of multi-material joining capability, galvanic corrosion performance, and predictive modeling of galvanic corrosion of multi-material Mg-Al joints.

Reviewer 3:
This project falls squarely in greenhouse gas emission reduction via increased use of lightweight materials in dissimilar material joints. Strength reduction via corrosion is a significant roadblock to broad application of dissimilar material joints.

Reviewer 4:
Better understanding of weld practice/methodology on microstructure, as well as prediction of weld performance of lightweight alloys support the overall DOE objectives of vehicle lightweighting. Subsequently, this contributes to achieving DOE fuel efficiency goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources appear to be sufficient to achieve the work outlined in this project.

Reviewer 2:
The resources seem sufficient. Per the author's own estimates, 33% of the work has been completed against 34% of the budget spent.

Reviewer 3:
This program's resources seem sufficient to enable completion of partner tasks and a successful team as a whole.

Reviewer 4:
Current burn rate indicates the budget expenditures seem to match the timing and accomplishments (each at about one-third of completion) pretty well.

Presentation Number: mat152
Presentation Title: A Hybrid Physics-Based, Data-Driven Approach to Model Damage Accumulation in Corrosion of Polymeric Adhesives
Principal Investigator: Roozbeh Dargazany (Michigan State University)

Presenter

Roozbeh Dargazany, Michigan State University

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

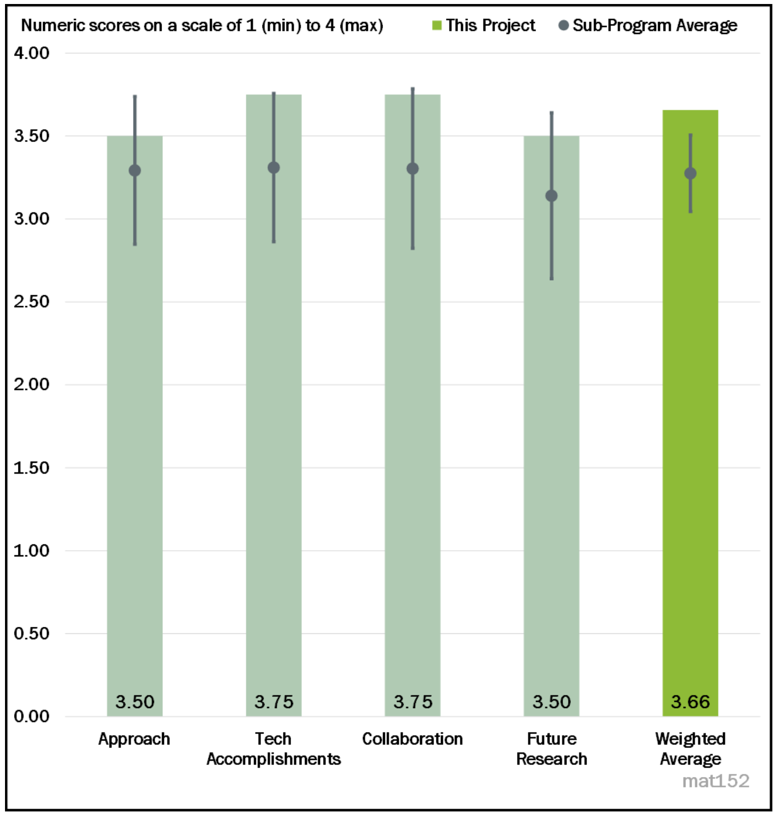

Figure 6-16 - Presentation Number: mat152 Presentation Title: A Hybrid Physics-Based, Data-Driven Approach to Model Damage Accumulation in Corrosion of Polymeric Adhesives Principal Investigator: Roozbeh Dargazany (Michigan State University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach is excellent and well designed.

Reviewer 2:

For modeling and computational methods, the project is well designed, and the tools used make the expected results are feasible. The modeling approach is excellent for deriving the various models needed and validation with good experimental results for corrosive effects from thermo-oxidation, photo-oxidation, hydrolysis, and hygro-thermal. The approach used for investigating and modeling aging mechanisms is related very well with the critical components that comprise an automobile. The project approach addresses technical barriers for the lack of constitutive modeling capabilities to predict corrosive effects and predictive modeling tools that are validated and have a prediction error of less than 10%. The approach does not directly address the technical barriers for a reliable joining technology for dissimilar materials and cost-effective tests for evaluation of corrosion. However, if the models are successful at predicting the corrosion mechanisms, then they will contribute to later development of reliable joining technologies and cost-effective tests. The conceptual approach for the theoretical model is well planned and supported with sound mathematical development of the parameters needed for a successful predictive model. One overall objective for a theoretical model to describe damage accumulation in constitutive behavior relative to five failure mechanisms is significant to a technical approach that will allow successful prediction of corrosion behavior. The milestone chart demonstrated a well-planned approach with partner participation from the initial development of a theoretical platform through identification of damage mechanisms and failure characterization to the end goal of software predictions and model validation using test samples exposed to a combination of corrosion mechanisms. The modeling approach is well coupled with the selection of materials and criteria needed for experimentation to obtain data for validating the models. The proposal to include a physics-informed cluster of super-simplified neural network engines is a novel addition to the end of the modeling effort.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Very good progress has been made.

Reviewer 2:
The technical accomplishments achieved at the current stage of research are sharply focused on the critical barriers that challenge the development of predictive models and address many aspects of material failures due to corrosive effects. The performance indicators identified in the milestone chart have been met or are in progress with indications that all will be met once laboratory experimentation resumes. Observations from the experiments were significant to identify the symptoms and challenges associated with the data needed to populate the theoretical model. For example, chemical anomalies that occur between adhesives and two opposite effects for the same damage mechanism, such as both hardening and softening, or like effects from thermo- and photo-oxidative mechanisms. The mathematical modeling was well representative of the experimental results and technical challenges were identified throughout the project.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team includes academia, material manufacturers, Tier 1 suppliers to the automotive industry and subject matter consultants. The organization chart effectively presented the involvement and coordination of all partners comprising the product team and identified their respective responsibilities that are integrated for all aspects of the model development. The modeling tool being developed will be extremely beneficial to material developers and parts suppliers.

Reviewer 2:
This reviewer observed very good collaboration between supplier tier and university team.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The proposed research is very well planned.

Reviewer 2:
The proposed future research focused on extending the current model to include data from real-world environments, integration of other damage mechanisms than those currently evaluated, and screening tests for training and validation of the model during use by a materials developer. This is a logical and reasonable approach to further development and improvement of the model, although additional critical barriers and technical challenges have not been identified by DOE. There were no risks or risk mitigation strategies identified by the presenter; however, challenges were identified by the project team that indicate an awareness of where risks may occur.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project supports DOE goals of lightweighting by enabling understanding of basic bulk material joining materials.

Reviewer 2:
This project supports the overall DOE objectives for improved integrated computational materials engineering frameworks for predictive modeling of advanced materials and prediction of corrosion-countering effects on functional resins and adhesives used in joining dissimilar materials. To some degree, the models being developed will support innovations enabled through the use of machine learning and artificial intelligence for material development and manufacturing processes.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources for funding ($1.4 million for 3 years) to support a project team of 6 partners is sufficient for the development, limited experimentation, and validation of the hybrid physics-based model for damage by corrosion of polymeric adhesives. Milestones were achieved in a timely manner with delays occurring only because of a worldwide pandemic.

Reviewer 2:
The reviewer noted sufficient use of resources based on budget.

Presentation Number: mat153
Presentation Title: Multi-Scale Computational Platform for Predictive Modeling of Corrosion in Aluminum-Steel Joints
Principal Investigator: Miki Banu (University of Michigan)

Presenter

Miki Banu, University of Michigan

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

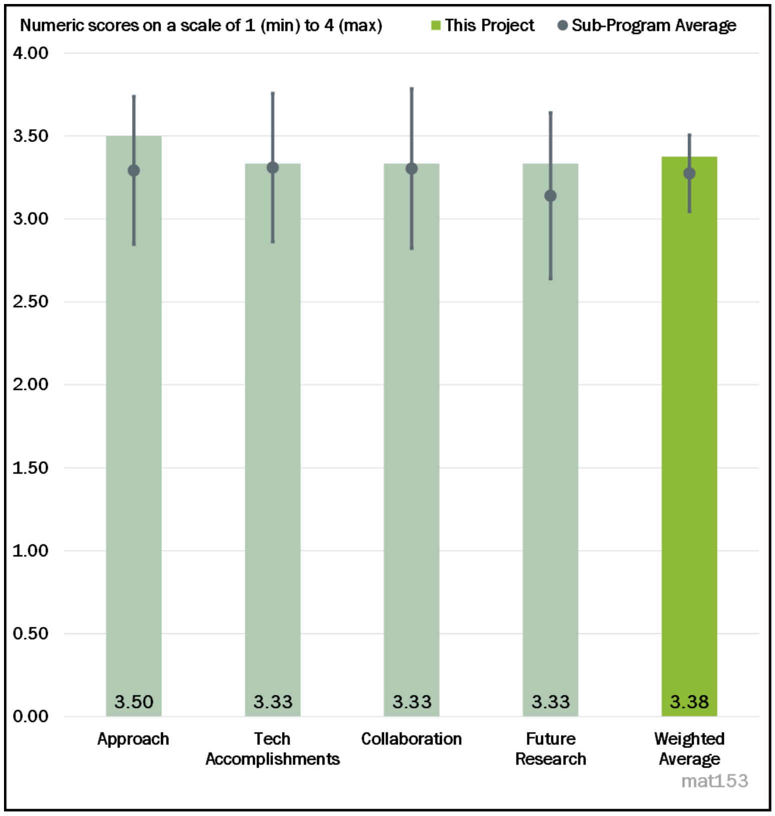

Figure 6-17 - Presentation Number: mat153 Presentation Title: Multi-Scale Computational Platform for Predictive Modeling of Corrosion in Aluminum-Steel Joints Principal Investigator: Miki Banu (University of Michigan)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Great approach to a most difficult subject. Technical barriers were addressed and executed using a well-designed approach.

Reviewer 2:

The approach for this project encompasses a well-designed ICME framework with multi-scale modeling and complimentary experimental validation.

Reviewer 3:

The approach to performing the work seems to be logical. A better job could be done in tying the various aspects of the approach together for better understanding of why each element is important, and how the parts tie together to accomplish the desired goal(s).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed excellent progress towards achieving the technical barriers in a timely manner.

Reviewer 2:
The accomplishments to date are on track. The flow of the fundamental science learned into the applied models appears to be progressing well. The deliverables themselves are also useful tools for the engineering community.

Reviewer 3:
It was difficult to understand how the current accomplishments contribute to the overall goals. There was some important information left out of the presentation of accomplishments that would have contributed to better understanding what was done and how they contribute to the eventual goal. The accomplishments currently read as a set of tasks that had been carried out. The project team does not actually describe what was achieved with regard to completion of tasks and how these contribute to the final goal(s).

Some of the acronyms used were not defined—RSW (resistance spot weld), SPR (self-pierce rivet). The authors should not assume that everyone in the audience knows these acronyms. No information was given about the composition or concentration of the salt solution used in corrosion testing. It also appears the tests were both General Motors (GM) and University of Michigan (UM) test protocols. For what does the GM protocol test? Salt exposure could simulate many things; so, what was this test(s) simulating? This was the same for the UM tests.

What was the conclusion or observation on the effect of the identified intermetallic compound on corrosion resistance of the welds? There was mention of the Al-Fe intermetallic changing from ductile to brittle upon corrosion exposure. What is the significance of this in the grand scheme of things and with regard to material degradation? For instance, does this affect stress corrosion cracking? Are there additional effects on the metal matrix with regard to the intermetallics?

What is the basis in the stress corrosion cracking (SCC) model for combining the slip dissolution model with a modified phase-field model, a decohesion model for hydrogen embrittlement and a peridynamics model?

There is lack of a single expression for any of the predictive corrosion model(s) being worked on, not even a preliminary expression. One would be good.

For corrosion nucleation, what does the project team define as nucleation? What are the parameters being used to bound the nucleation event and to separate it from propagation? What length scale is the project team working at in the nucleation phase?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This was presented as a good cohesive program, with the partners all working well together.

Reviewer 2:
The reviewer noted a very good collaboration across the project team.

Reviewer 3:
This is difficult to gauge. The majority of the work reported seems to have been carried out by UM. Perhaps the authors could shed more light on the contribution of the other team members in future presentations. Additionally, there is no mention about how communication is maintained amongst the team members. One presumes that regular team meetings and interactions occur as needed.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The proposed future research to complete the program is well thought out with appropriate deliverables and timelines and a proposed strategy to overcome barriers to technology implementation.

Reviewer 2:
The plan to completion is well defined.

Reviewer 3:
More attention needs to be paid to model validation activities, which are of no use if the model can only accurately describe the data collected by the workers. The reviewer further commented that SN-curves typically do not take the effect of aqueous environment into account. How do the authors propose to use the SN curves they gather to predict failure when there is a likelihood of environment playing a role in fatigue failures with these Al-joints?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The development of predictive tools to manage degradation of welds and joints is important for the effective use of lightweight materials for auto bodies.

Reviewer 2:
This program directly supports the DOE multi-material systems objectives.

Reviewer 3:
Predictive modeling of multimaterial joints supports the DOE objectives of increased efficiency through lightweighting.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources for this program appear to be sufficient.

Reviewer 2:
Resources were sufficient and effectively used to achieve project objectives.

Reviewer 3:
Based on the figures presented by the authors indicating percentage of work completed, the funds seem to be adequate. However, it is difficult with the limited information at hand for the reviewer to independently confirm whether the remaining funds will be adequate to complete the work and achieve the stated project objectives.

Presentation Number: mat162
Presentation Title: Machine Learning and Supercomputing to Predict Corrosion/Oxidation of High-Performance Valve Alloys
Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

Presenter

Dongwon Shin, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 20% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

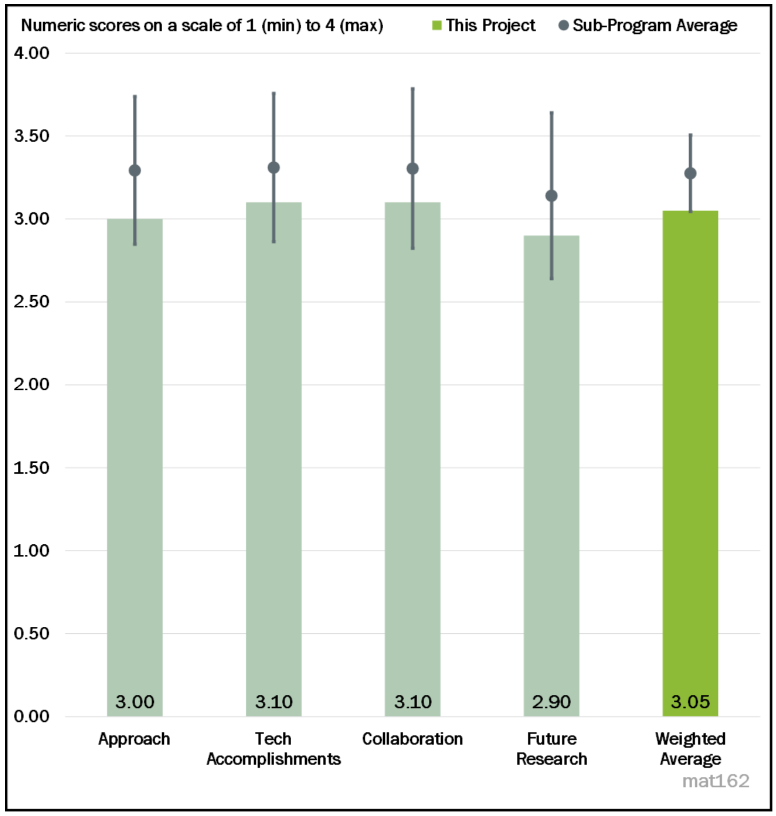

Figure 6-18 - Presentation Number: mat162 Presentation Title: Machine Learning and Supercomputing to Predict Corrosion/Oxidation of High-Performance Valve Alloys Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

There is currently a wide range of research works taking place related to corrosion and oxidation of automotive engine valve at collaborating institutions and private companies. Computational and experimental work addresses the different components corrosion and surface chemistry at high temperatures. Of the major activities proposed, the first one is to develop different computational tools to predict and understand progress and behavior of corrosion or oxidation to the alloy used for automotive valve. The second is to conduct the simulation to understand the correlation between advanced alloy features and oxidations process. The third is to understand the thermodynamics and kinetics during the evolution of the oxidations process of the valve. The last is to predict oxidation behavior from the advanced alloy features with high accuracy using molecular dynamics (MD) simulations.

Reviewer 2:

It is not clear how and what kind of machine-leaning technique is being used to achieve the goal of “Predict alloy oxidation as a function of alloy chemistry and temperature and experimentally validate within 10% accuracy”. Additionally, one of the major barriers listed in the proposal is “Lack of fundamental alloy oxidation data (e.g., atomic mobilities in oxides, oxygen permeability)” However, the proposed research does not seem to have a task to directly address this barrier. Most of the tasks focus on simulation; validation of these simulation results should be equally, if not more, important.

Reviewer 3:
Focus is mostly on computational methods development to surmount technical barriers even though an experimental setup at ORNL is detailed. How will results from the computational methods be tested on real materials?

Reviewer 4:
This reviewer appreciated the fundamental background on corrosion mechanisms but had concerns that the corrosion rig test data lacked the dynamic forces due to valve actuation and cylinder pressure loading. These mechanical contributors will not be accounted for in any spallation prediction unless a subsequent correction is made, perhaps by finite element simulation or access to other test data. This work appears to only focus on the alloy chemistry and temperature effects, and is going about these efforts in a systematic method—drawing from both machine learning techniques and physics-based approaches.

Reviewer 5:
This reviewer was not clear on the approach. It sounds as though the project team is taking data, fitting a semi-empirical equation to the data, and then using the fitted coefficients to train a machine learning model. Because machine learning is essentially a fit, it appears that the project team is fitting a machine learning model to fitted parameters. Why not train the machine learning directly on the oxidation data?

Additionally, the reviewer remarked that the project team is applying its model to material in air and water vapor. What about the combustion products?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
This reviewer thought that investigators made very good progress. Excellent strengths of this project are systematic approaches regarding development of the computational tools.

Reviewer 2:
Modeling has identified key features that influence oxidation, project plan states it is on track but many of the milestones lay ahead in the fourth quarter (Q4) of 2020.

Reviewer 3:
The reviewer commented that work is progressing according to schedule.

Reviewer 4:
The project presented several interesting results. The correlation between predicted-parabolic rate constant (Kp)/experimental-Kp is plotted in log-log scale. The actual variation could still be several orders of magnitude off, especially for a wet environment. It is interesting to know what the input of ML-based prediction is in addition to chemistry composition. It is good to see the use of super-computing facility in ORNL for atomistic simulations. A methodology should be developed to validate the simulation result.

Reviewer 5:
This reviewer stated that the model seems to be predictive for nichrome (NiCr) alloy oxidation with sources of uncertainty identified. What other alloys will be attempted? Not clear how the various components of this project are integrated towards driving overall project success. Who is doing what? Who is using data/information from whom?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
From the presentation it is very clear that the coordination between the three institutes is good, and the major research of this project is a highly interdisciplinary character.

Reviewer 2:
The team of ORNL and Penn State University (PSU) is a good combination. The roles of American Society for Metals (ASM) International and Tenneco powertrain are unclear in this project.

Reviewer 3:
The reason why finite element analysis is needed is not clear. What has each partner contributed to-date? How are ReaxFF simulation results being used to support finite element simulations? A brief outline of the tasks required of each participant and who has delivered what to date would be very helpful.

Reviewer 4:
The contributions from ORNL and Penn State are discussed in detail. The input from the industry partner Tenneco is unclear.

Reviewer 5:
This reviewer asked how the project team coordinates among the various institutions.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The plan seems good.

Reviewer 2:
The strength of this project is very well planned and organized. Each step is very logical. One of the reviewer's concerns is related to the first principle calculations. Density functional theory (DFT) technical procedure is not clear from the presentation, specifically the RearxFF for MD simulation. It is not clear why investigators used only two different temperatures for MD simulations or only two diffusion rates. It will be better if investigators use a couple of different time scales to compare the corrosion rates at high temperatures.

Reviewer 3:
Most, if not all, of the proposed efforts focus on simulation. Some efforts should be proposed to validate those simulation results.

Reviewer 4:
How are results of the proposed future research, which is largely computational, to be used to guide experiments to test the model predictions? This is unclear to the reviewer. It seems that the focus is on computational methods development and less on new materials development. No clear path to testing model predictions was observed by the reviewer.

Reviewer 5:
A high-level data flow diagram was supplied to show how the computational pieces fit together. The supplemental machine learning material shows how machine learning can reduce experimental trials. The proposed future research appears to include expansion of the features considered, but does not clearly show how these future endeavors tie back to the project goal or will result in a final outcome/milestone. What key questions are driving these activities? What is the link between these simulation activities and a final deliverable or insight gained?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Yes, focus is on improving oxidation resistance of metallic parts in high temperature engine environments.

Reviewer 2:
Fundamental research into higher temperature valve alloys supports higher power densities in internal combustion engines.

Reviewer 3:
The reviewer described this project's relevance as good.

Reviewer 4:
Yes, this project supports the overall DOE objectives. The performance of an automotive engine is depending on the corrosion or oxidation rate of the materials. New materials are needed for the fuel efficient, next generation engine, which has high corrosion resistance. In this project, proposal investigators explained the systematic approach to predict the corrosion or oxidation rate of the materials or alloys. The investigators' main goal is to develop new computational tools. Combined with the experimental and computational approach it is possible to have broad impact on the development of cost-effective, environment-friendly automotive valves for future generation.

Reviewer 5:
Corrosion prevention is important for vehicles, but how the outcome of the project can be used is not clear.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
ORNL and PSU have the required experience and expertise for the proposed work.

Reviewer 2:
Funding appears sufficient for the stated goals.

Reviewer 3:
Good project resources were indicated by this reviewer.

Reviewer 4:
It seems that the project has sufficient resources but suffers from a lack of clearly defined integration.

Reviewer 5:
Although, investigators made some progress regarding computational tools development, there are some unsolved questions. This reviewer's major concern is about the progress of the project. From the presentation, it is clear that investigators completed only 50% of the project. How will they finish the remaining 50% of the project and use the resources in one year?

Presentation Number: mat163
Presentation Title: Multiscale Modeling of Corrosion and Oxidation Performance and Their Impact on High-Temperature Fatigue of Automotive Exhaust Manifold Components
Principal Investigator: Mei Li (Ford)

Presenter

Mei Li, Ford

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

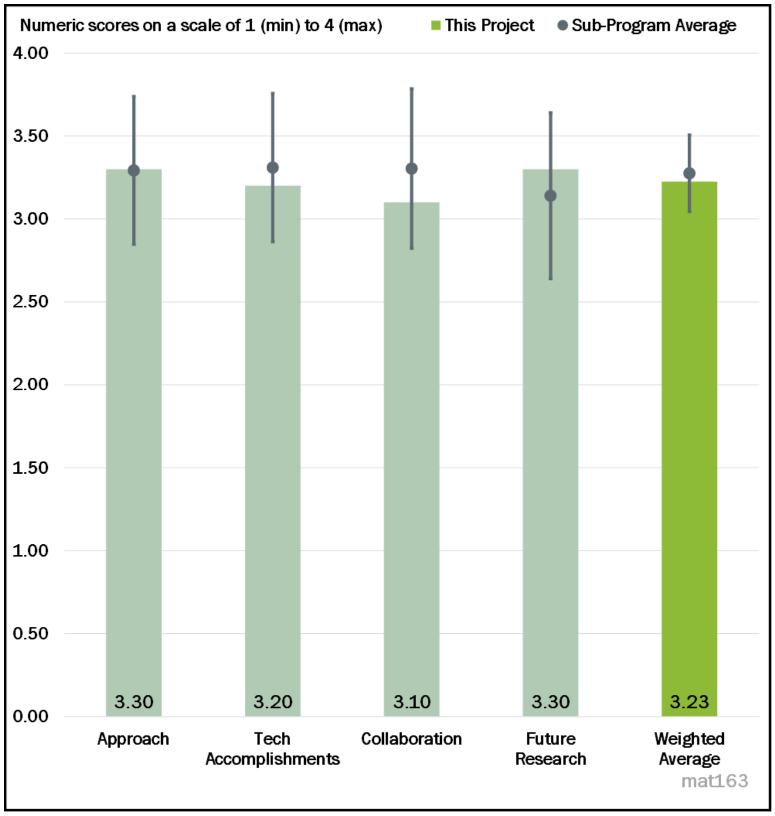

Figure 6-19 - Presentation Number: mat163 Presentation Title: Multiscale Modeling of Corrosion and Oxidation Performance and Their Impact on High-Temperature Fatigue of Automotive Exhaust Manifold Components Principal Investigator: Mei Li (Ford)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The increased temperatures necessary for lowering carbon emissions in internal combustion engines creates an issue with any current materials commonly in use. This work was clearly targeted and well executed to move new material opportunities into the application.

The activation relaxation technique for migration mechanisms was well applied and is an important asset in this work. Much has been done on the applied thermal stresses, but this type of modeling puts the entire microstructure including the changes induced during operation into the model. Oxidation is a major concern for these components, and this work has the capability to improve that issue.

Working on exhaust manifolds is not the usual type of exciting-sounding project, but the ability to increase exhaust out temperatures gives engineers a new space to work in for combustion recipes, and this is the type of work that lays the foundation for further decreases in carbon emissions.

Reviewer 2:

Currently, there is a wide range of research related to corrosion and oxidation of automotive engine at three institutions and Ford Motor Company. Computational and experimental work addresses topics in alloy fatigue at high temperatures, corrosion, and surface chemistry. Of the major activities proposed, the first one is to develop a computational tool to predict and understand corrosion or oxidation behavior of the alloy used for automotive engine. The second is to conduct the experiment on the statics and cyclic corrosion or oxidations process on the alloys. The third is developing a corrosion or oxidation fatigue model at high temperature for the alloys. The last are experimental observations of the computational model.

Reviewer 3:
Experimental and analytical work appear to be on different scales. Linking/reconciling the two may be a challenge with the remaining project time.

Reviewer 4:
Important work of corrosion fatigue life prediction for ferrous component is undertaken in this industry led effort. Models in this area are lacking and an ICME approach can help the field advance.

Reviewer 5:
The approach seems reasonable.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Overall progress is good.

Reviewer 2:
Alloy elements appear to show improvement in corrosion performance.

Reviewer 3:
Application of the modeling was well done with significant improvements over prior works in this area. The increase in exhaust temperature allowed by the materials proposed in this work can make a substantial difference in options for the combustion recipe of internal combustion engines. This work is applicable to different types of fuels, and therefore has a broad application in the market.

Reviewer 4:
The proposal aims to develop computational tools that predict corrosion and oxidation performance and their impact on high-temperature fatigue of automotive exhaust manifold components in collaboration with Ohio State University, Missouri Science and Technology, and Oak Ridge National Laboratory. From the presentation it is very clear that the investigators completed some major steps so far. They should accelerate the remaining part of the project.

Reviewer 5:
While progress is being made, a comment is made about the differences in the scale of computational and experimental approaches. For example, while the ReaXX force field and other approaches may have merit, the predictions are at a time and spatial scale that are not being accessed or even considered in the experiments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
From the presentation it is very clear that the coordination between the three institutes is good, and the major research of this project is a highly interdisciplinary character.

Reviewer 2:
This is an industry-led team with university and National Laboratory partners. The team has expertise in place for the project.

Reviewer 3:
Partners and responsibilities were listed, but it is unclear if the separate entities worked independently or if they built off of each other’s work.

Reviewer 4:
It would be helpful if the project team could provide more information about how the various part of the team interact and coordinate the work.

Reviewer 5:
The presenter did not convey a strong understanding of the computational models being employed by the project and this could increase the risk of errors and missed opportunities.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The reviewer remarked that proposed future research looks good.

Reviewer 2:
Next logical steps are provided for simulation work as well as an appropriate proposal to upgrade fatigue rigs to better mimic real-world conditions.

Reviewer 3:
Excellent strengths of this project are the systematic approach about developing the computational tools. This reviewer inquired about the first principle calculations. The DFT technical procedure is not clear from the presentation, specifically the potential energy surfaces. It is not clear why investigators used only two different temperatures for MD simulations or only two diffusion rates. It would be better if investigators used a couple of different time scales to compare the corrosion rates at high temperatures.

Reviewer 4:
The proposed work in DFT calculations is a significant opportunity. The work on corrosion and oxidation is very necessary and should yield some applicable opportunities. However, there needs to be more focus on the opportunities available beyond just transmission electron microscopy (TEM) and scanning electron microscope (SEM) characterizations.

Reviewer 5:
There is no fatigue modeling planned in the future effort. Some larger scale modeling will be helpful to compare with lab experimental data that will be generated.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This reviewer described project relevance as good.

Reviewer 2:
Corrosion fatigue is of concern in powertrain exhaust components and other components as well. The project supports the DOE VTO materials program objectives.

Reviewer 3:
Predictive capability for corrosion and oxidation performance in automotive exhaust manifolds as well as new corrosion resistant alloy development enables greater power density in internal combustion engines through higher temperature operation.

Reviewer 4:
Yes, the project supports overall DOE goals. The engine performance depends on the corrosion or oxidation rate of the materials. We need new materials for our fuel-efficient, next generation engine, which has high

corrosion resistance. In this project proposal, investigators explain the systematic approach to predict the corrosion or oxidation rate of the materials or alloys. The investigators' main goal is to develop new computational tools. Combined with the experimental and computational approach, it is possible to have a broad impact on developing a future generation engine.

Reviewer 5:
The work on exhaust manifolds, as with all materials on components exposed to combustion gasses, is an essential work in creating a larger combustion recipe space for engineers doing engine calibrations. The usual combustion regime is defined by the ability of materials at every point in the process. This includes things like thermal rupture on pistons, exhaust valve beat in, and deposit formation at ring lands. Without research into the ability to create cost effective materials options for components, the opportunity to increase the efficiency of internal combustion engines is very limited.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources appear sufficient to meet project goals in the stated timeline.

Reviewer 2:
Resources are sufficient.

Reviewer 3:
Good resources were observed by this reviewer.

Reviewer 4:
Although, investigators made some progress regarding computational tools development there are some unsolved questions. The reviewer's major concern is about the progress of the project. From the presentation, it is clear that investigators completed only 40% of the project. How will the project team finish the remaining 60% of the project and use the resources in one year?

Reviewer 5:
This is a great milestone check point but with the project only 40% complete, the big opportunity for component level demonstration lies ahead of the team. That will be the metric to prove if the resources were sufficient, if a failure mode is discovered that was not tested prior to that, or if the resources were insufficient. All PIs make decisions based on budget and level of acceptable risk. The higher the budget, the lower the acceptable risk. That is when these questions will truly be answered.

Presentation Number: mat164
Presentation Title: Multiscale Development and Validation of the Stainless Steel Alloy Corrosion (SStAC) Tool for High-Temperature Engine Materials
Principal Investigator: Michael Tonks (University of Florida)

Presenter

Michael Tonks, University of Florida

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

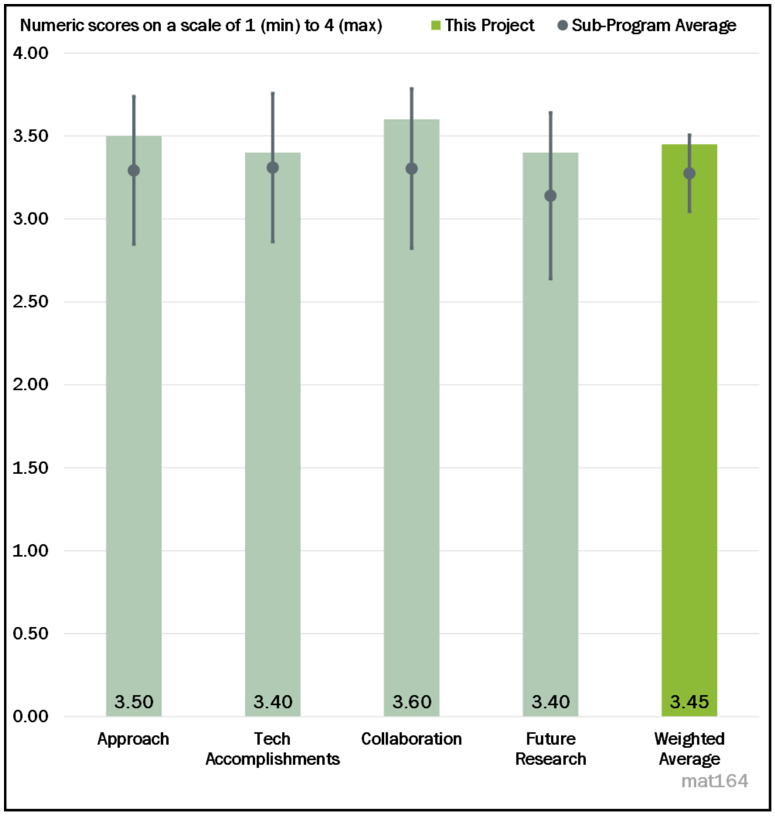

Figure 6-20 - Presentation Number: mat164 Presentation Title: Multiscale Development and Validation of the Stainless Steel Alloy Corrosion (SStAC) Tool for High-Temperature Engine Materials Principal Investigator: Michael Tonks (University of Florida)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

There is currently a wide range of research works going related to corrosion and oxidation of stainless steel alloy and related materials at University of Florida and other collaborating institutes. Using computational and experimental tools, this project is addressing one of the essential engine valve components. The major activities proposed including developing open source tools to model the corrosion of the different engine valves (21-2N, 21-4N, and 23-8N) at extreme conditions such as high temperature and pressure; quantifying the effect of micro-structures and alloy composition on valve steel corrosion; validating the mesoscale modeling with the help of the experimental tools; and releasing the stainless steel alloy corrosion (SStAC) tool.

Reviewer 2:

The project uses a multi-scale modeling approach to develop a tool that models corrosion behavior of stainless steel in an exhaust environment. Successful tool development could be useful.

Reviewer 3:

The approach is very focused on addressing the identified barrier of predictive modeling for corrosion of high temperature materials, specifically valves. The model development uses a multi-scale approach ranging from atomic scale to mesoscale and includes model validation using experimental results and actual full-scale engine data. The approach allows for a well-designed project that is very feasible based on modeling of materials at all levels and using experimental and operational data for validation of the modeling results. The model is based on an established platform for multi-physics objected oriented simulation developed by a

National Laboratory. The tasks identified in the project schedule Gantt chart show a logical progression of research and development of a successful tool.

Reviewer 4:
A lack of predictive modeling information for stainless steel alloys is lacking in high temperature zones that will be needed for high efficiency combustion regimes. The approach implemented by the PI is a good balance of modeling, laboratory experiments, and validation. It integrates both a nice balance of experimental and real-world data to develop the model inputs. The nano- to millimeter progression provides the baseline information to develop and assess accuracy of the corrosion model. The first publication related to this research will be released in a few months. Additionally, the reviewer noted very solid go-no/go criteria.

Reviewer 5:
This project aims to predict oxidation/corrosion behavior of stainless steel, one of the most important alloy systems for vehicles technology applications by combining different length scale simulations (i.e., density functional theory calculations at the atomistic scale, phase-field/FEM for mesoscale, and experiments). However, the handshake/data exchange between two different length scale and time scale appear to be too simple of a linear synthesis.

Most importantly, the alloy systems that the team is currently working on are too simple model alloys. The project team cannot efficiently represent engineering alloys that matter to the VTO mission space. The PI is also aware of this critical gap; however, it does not look like the team has a plan to fill this gap. In the same topic, the information that can be obtained from the atomistic length scale (e.g., DFT simulations to derive point defects and activation energies of migration) are also limited to a very simple binary/ternary system. The reviewer was skeptical about how this approach can be expanded to the higher-order multi-component systems.

For the bigger length and longer time scale, the current approach has to calibrate the model using literature data. How certain can the literature data efficiently be translated to the model used within? Are all of the features—grain size, fabrication method, heat treatment conditions—the same/similar to be used in the current model? Also, if there are no literature data to calibrate the model to make a 'pure' prediction, what is the contingency plan?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The proposals aim is to develop a multiscale model and validations of the SStAC tools at high temperature for engine materials in collaboration with University of Wisconsin-Madison, Idaho National Laboratory (INL), and Tenneco. Until now, the investigators' performance is outstanding.

Reviewer 2:
Simulations and experiments were performed to validate modeling data. Because the manganese oxide layer helps with performance, it is important to understand how this function will then impact the modeling and understanding of the alloy properties. From the project tests, it appears that manganese content is critical to the material performance at high temperature.

FEA was performed to assess corrosion, temperature, and mechanics on materials. This FEA was built on INL's Multiphysics Object Oriented Simulation Environment (MOOSE). This modeling integrated the impact of the alloy elements.

Reviewer 3:
The experimental data to evaluate corrosion condition seem to be the mass variation only. Does the PI consider including microstructure information? The environment created for corrosion experiment (CO_2 gas) is different

from real exhaust environment. It is interesting to know if the corrosion behavior is very different in real exhaust environment where a high concentration of oxides of nitrogen (NO_x) exists.

Reviewer 4:
The team made good progress in terms of what it promised last year for the computational tasks. However, more details on the technical accomplishments would have been appreciated. It is rather surprising that there are only three working slides in this section. What the project team accomplished is that of simple ternary model alloys with only two chemical variations—221Cr-2Ni-8.5Mn and 23Cr-8Ni-1.5Mn—based on too many assumptions. Also, it is not clear how chemical sensitivity is captured in the atomistic simulations. For example, vacancy energy formation and Fe vacancy migration energy in Slide 8 were computed at different alloy compositions?

Also, the progress on the mesoscale phase-field model appears to be a bit behind. Given the fact that phase-field modeling requires a lot of parameters within—interfacial energy and atomic mobility within both multicomponent alloys and oxides—the reviewer wondered how this information has been obtained and will be obtained to make predictions. On the other hand, progress on experimental tasks looks good. The team got samples from the cost-share partner that has a direct relevance to VTO, which is important.

Reviewer 5:
The technical accomplishments achieved for the first half of the project show good progress as measured against the tasks and performance indicators (milestones) shown in the project schedule Gantt chart. The schedule shows the first three subtasks under Task I were completed, but the technical accomplishment slides indicate that the atomistic and mesoscale models are still being developed. Some of the data could not be explained by the presenter because it came from one of the partners. The corrosion model results show that the experimental data obtained for the two alloys compare well with the literature data. The presenter did not address why variation for the error bars was so high (25% instead of a typical 15%) or why the mass variation inverted for the two alloys studied at temperatures higher than 700°C. This could indicate that the model may not be able to predict accurately at the higher temperatures. Nothing was presented on the phase field (PF) model development. Reliability of the material properties was a concern by one of the reviewers at last year's merit review of this project. There are two more sets of experiments planned; hopefully, the data will improve the model so it can be used effectively to overcome the barriers.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team consisted of a National Laboratory as well as industry and academic partners. There appears to be excellent coordination between all project partners.

Reviewer 2:
It is very clear from the presentation that coordination between the three institutes is good, and the major research of this project is a highly interdisciplinary character.

Reviewer 3:
Each team in the project has its strength and complement with each other.

Reviewer 4:
The team has good collaboration and coordination.

Reviewer 5:
The partners include a university, a National Laboratory (for consulting on the model development), and an automotive parts manufacturer. There was no indication by the presenter regarding the degree of collaboration and coordination. The cost share indicates that the industry partner will cost share in-kind by using their testing facilities. The collaboration is mostly between the university and the parts manufacturer. Federal-Mogul is

mentioned at the end of the presentation, but the presenter did not describe this company as part of the collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The project plan is excellent. The SStAC tool is a distinct outcome of this project. This tool will permit the development of lower cost, better performing alloys for valve applications in difficult operating environments.

Reviewer 2:
The experimental component of proposed research is relevant and it is great to see that the team plans to disseminate the computational tool used within the project as open-source code. It would be great if the team can put more effort into expanding the demonstrated approach to high-order multicomponent systems.

Reviewer 3:
Although investigators made some progress regarding computational tools development, there are some unsolved questions. One question is related to the first principle calculations for different properties of the alloys. Investigators did not specify what properties will be explored.

Reviewer 4:
Items listed in "Remaining challenges and barriers" are indeed critical for the successful development of the tool. The future research should be related to efforts in addressing these barriers. What methodology will the project team use to validate the developed SStAC tool?

Reviewer 5:
The proposed future research is for continuation of the project through the end of the performance period. The project team does not fully address the remaining challenges described in the preceding slide. The remaining challenges and barriers will need to be addressed to overcome the overall barriers of predictive modeling of corrosion sensitization to aid in high-temperature valve design.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project supports the overall DOE objective for improved integrated computational materials engineering frameworks for high-temperature automotive engine components.

Reviewer 2:
Yes, this project supports the overall DOE objectives by providing the knowledge needed to develop materials for lower cost, higher efficiency engines.

Reviewer 3:
This project aims to predict the oxidation/corrosion behavior of stainless steel, one of the most important alloy systems for vehicles technologies.

Reviewer 4:
Modeling methodology and toll is important to reduce the amount of costing experiment needed for process/material development.

Reviewer 5:
Yes, it is. Understanding corrosion and protecting the engine from corrosion is the key component for developing new generation lightweight engines. Different kinds of computational and experimental tools for

the predictions and the impact of the corrosion in the engine is needed. In this project proposal, investigators explain the systematic approach to developing new tools to understand the complex feature of corrosion for stainless steel alloys. Combined with the experimental and computational approach, it is possible to have a broad impact on the development of fuel-efficient lightweight engines.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Yes, investigators have enough resources and are using it in a timely fashion.

Reviewer 2:
The project team has expertise and experience to finish the proposed task.

Reviewer 3:
The level of funding is sufficient for a 3-year program of predictive model development by two universities that will include experimentation for atomic-scale critical alloy properties, mesoscale corrosion evaluation, and engineering scale experiments by the parts manufacturer.

Reviewer 4:
This project appears to be on schedule and funding appears to be sufficient to complete all stated objectives.

Reviewer 5:
The team has the right amount of resources to execute the proposed research plan.

Presentation Number: mat165
Presentation Title: Directly Extruded High Conductivity Copper for Electric Machines
Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory)

Presenter

Glenn Grant, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

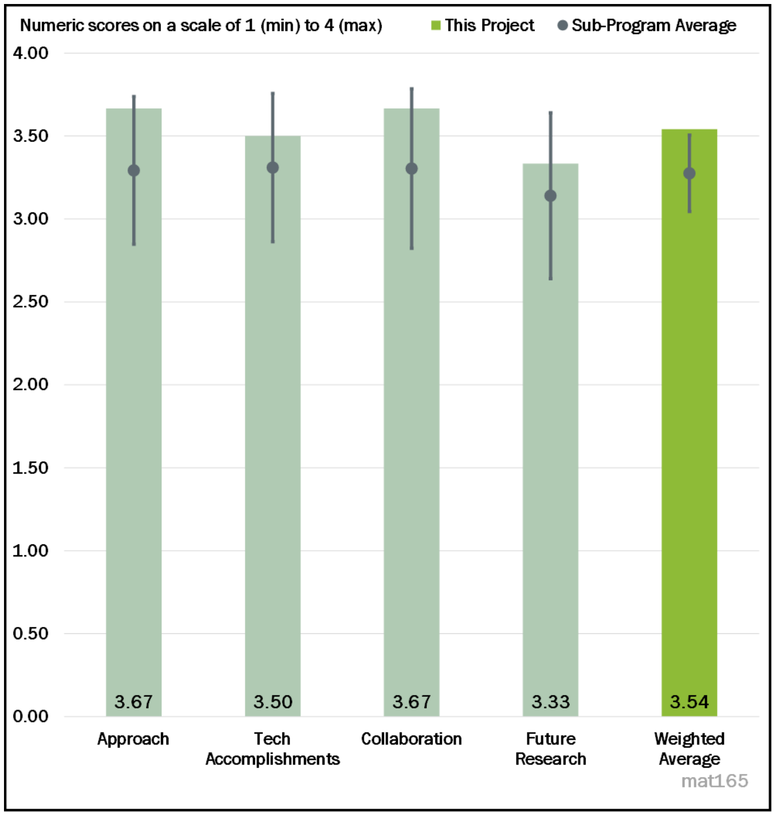

Figure 6-21 - Presentation Number: mat165 Presentation Title: Directly Extruded High Conductivity Copper for Electric Machines Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The project has clear goals. The team successfully utilized its experience and infrastructure from prior development to carry out the project and the result is promising.

Reviewer 2:
The approach to improve the electrical conductivity of copper (Cu) through carbon-based reinforcement and shape processing is technically sound.

Reviewer 3:
A 50/50 cooperative research and development agreement (CRADA) has been established to share costs with partner, General Motors. The project goal is to increase power density, which will require increasing flux density capacity. To accomplish this, higher conductivity materials at increased temperatures (higher than pure Cu) will be needed. Cu is already very conductive; the only Cu additive that increases conductivity is carbon. However, the form and amount of carbon that should be added to Cu to achieve the increased conductivity at high temperature (greater than 350 K) is not known. High conductivity at increased operating temperatures is critical to allow these materials to operate during electric motor operation.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The approach is reasonable and the project team (laboratory, industry, and university) has made appreciable progress within the scope of this effort. Scaling up to components and possible redesign of components to take advantage of improved electrical conductivity will require a separate and possibly larger effort.

Reviewer 2:
The reviewer wondered if the project team had microstructure data to evaluate the distribution of carbon nanotube (CNT) in Cu, and if it affects the final conductivity at high temperature. Long-term durability is indeed an interesting question to ask as indicated by another reviewer. It would be good to see effort related to it.

Reviewer 3:
To assess options, several forms of carbon were added to Cu using several bulk manufacturing processes to create this high conductivity Cu-C composite material. However, few bulk methods have shown promise; yet extrusion has been successfully used to achieve a high level of homogeneity. One type of extrusion processing called ShAPE was successfully used to mix and extrude wire and bar with the homogeneous mix of Cu-C composite material and can create fully dense wires from all graphene precursors. Graphene content ranges up to 6 parts per million (ppm), the graphene precursor material showed promise and very low levels of graphene increase conductivity over Cu. Continuous forms of carbon, carbon layers, bulk materials have been made defect free. The mechanical properties of Cu-graphene composite are similar to pure Cu.

Through FEA, more improvements in efficiency is possible by increasing graphene content. By increasing the graphene content, this could improve the composite material closer to the theoretical percolation limit of 150% International Annealed Cu Standard (IACS), which equates to 150% of the conductivity of pure Cu.

A material with high conductivity (and higher current carrying capacity) can reduce Cu loss (I^2R losses). This Cu-C matrix composite material has properties that can contribute to significant motor efficiency improvements.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration between the team members is excellent.

Reviewer 2:
This reviewer stated that the collaboration complements with each other.

Reviewer 3:
A path to commercialization is being established with the partners participating in this project. Several industrial motor suppliers have already expressed interest in this material.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The project is nearing completion and a new effort will be required to implement the findings of this effort.

Reviewer 2:
Is there a calculation regarding the theoretical improvement on conductivity as a function of graphene content? If yes, how does the current value compared to the theoretical limit?

Reviewer 3:
A bulk manufacturing process still needs to be established. A challenge still exists; how much graphene is the optimal amount? The temperature coefficient of resistance (TCR) should continue to decrease as the graphene content is increased. The resulting materials property improvements by graphene integrated into Cu is still not understood. A very large internal PNNL initiative is now investigating the fundamental relationship of the graphene with Cu.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Yes, this project supports overall DOE objectives by providing the knowledge needed to develop materials for lower cost, higher efficiency engines.

Reviewer 2:
The project is relevant for DOE's electrification objective.

Reviewer 3:
The project proposes to develop/modify material for motors, which is in line with DOE goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This project appears to be on schedule and the funding appears to be sufficient to complete all stated objectives.

Reviewer 2:
Resources are sufficient to close out the current effort.

Reviewer 3:
The team is expected to finish (have finished 98%) what it proposed to do.

Presentation Number: mat166
Presentation Title: Aluminum Purification and Magnesium Recovery from Magnesium-Aluminum Scrap
Principal Investigator: John Hryn (Argonne National Laboratory)

Presenter

John Hryn, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

67% of reviewers indicated that the project was relevant to current DOE objectives, 33% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

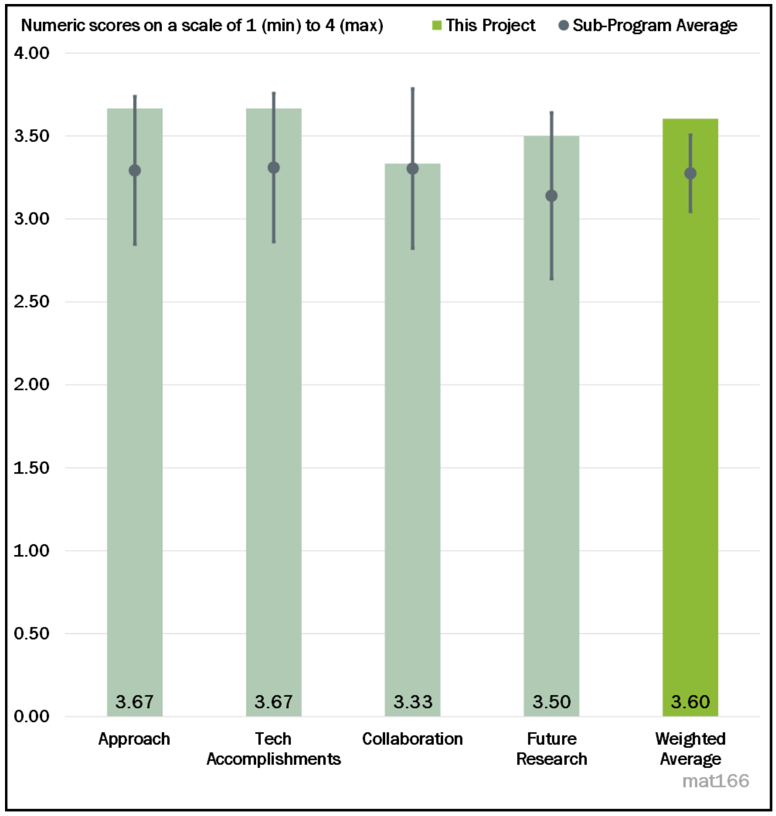

Figure 6-22 - Presentation Number: mat166 Presentation Title: Aluminum Purification and Magnesium Recovery from Magnesium-Aluminum Scrap Principal Investigator: John Hryn (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project approach seems very clear and well focused to address the technical barriers of providing a novel, reduced cost, environmentally friendly method of obtaining high purity Mg while also improving purity of recycled Al, and the approach seems well designed to accomplish that.

Reviewer 2:

This is a short, focused program on enhancing the recovery of Mg from Al scrap. The team has done a good job on delivering empirical results in a short timeframe.

Reviewer 3:

The electrolytic process to purify aluminum scrap is a good plan. All aspects including the scrap metal constitution, molten salt characterization for the electrolyte and materials for cell construction are considered. As proposed the process is continuously refining.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Technical accomplishments and progress seem quite impressive for such a short-term project and well in line with addressing the critical barriers related to increasing domestic supply of low-cost, environmentally friendly

Mg. The project also reduces aluminum recycling cost as well as providing a good basis for potential future scale up efforts.

Reviewer 2:
The lab scale trial is completed after determining materials for cell construction. Also, the electrolyte selection is completed. The lab scale experiment resulted in refining small quantity of magnesium from Al scrap material. The initial trial confirms the assumption of separating Mg from Al alloy without the use of chlorine treatment.

Reviewer 3:
Significant work has been accomplished in a timeframe of approximately 6 months. This includes developing and performing experiments that include several variables and achieving excellent results.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer observed appropriate team members on the project. Due to the short duration, it would be expected that the partners would need to be limited and streamlined to support.

Reviewer 2:
Good collaboration and coordination seem to be evidenced by the technical accomplishments. However, the presentation is not very detailed on who is doing what. Additionally, it is not clear if the industry partners are capable of scaling up and commercializing the process or if another industry partner will be required to accomplish this.

Reviewer 3:
This reviewer commented that a DOE lab is involved as the lead while one inventor and one testing lab are conducting the experiments in small scale. However, validation by any major producer needs to be obtained on scalability.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
Future research seems well planned to support scale up of technology for potential commercialization, although it is not clear if additional work will be funded because this project is claimed to be 99.9% complete.

Reviewer 2:
Regarding proposed future research, this reviewer noted increasing the cell size to check scalability. This may need another partner, major producer, or recycler, to check the feasibility.

Reviewer 3:
Technology scale up appears very reasonable going to 1 kA then 10 kA to ultimately 300 kA to exist within current smelters. One question is how long would these proposed future stages take and to what level of investment and partnership would need to be put in place to achieve?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project supports DOE’s lightweighting initiatives, providing a low-cost, high-volume method to extract Mg from Al scrap. This lessens national dependence on importing Mg while potentially offering a low-cost method of extracting from scrap Al.

Reviewer 2:
The project supports increased use of both lightweight Mg and Al alloys by proposing a lower cost, more environmentally friendly process of obtaining Mg domestically while also reducing the cost of providing high purity Al alloys from recycling waste stream.

Reviewer 3:
This does not directly contribute to the DOE objective; however, this project is relevant. Magnesium production is the primary objective and recycling of scrap is the secondary objective of the project. Reducing the dependency on external sources and effective recycling are the outcomes. It is necessary to complete the work as planned now, but further support will need to be secured from other sources.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Clearly, the team members were able to achieve the milestones rapidly with a relatively low investment.

Reviewer 2:
Although the budget seems thin for the amount and type of work being conducted, the project has nevertheless completed its work and appears to have met its goals within budget.

Reviewer 3:
No comments were indicated by this reviewer.

Presentation Number: mat167
Presentation Title: Corrosion Mechanisms in Magnesium-Steel Dissimilar Joints
Principal Investigator: Vineet Joshi (Pacific Northwest National Laboratory)

Presenter

Vineet Joshi, Pacific Northwest National Laboratory; Donovan Leonard, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

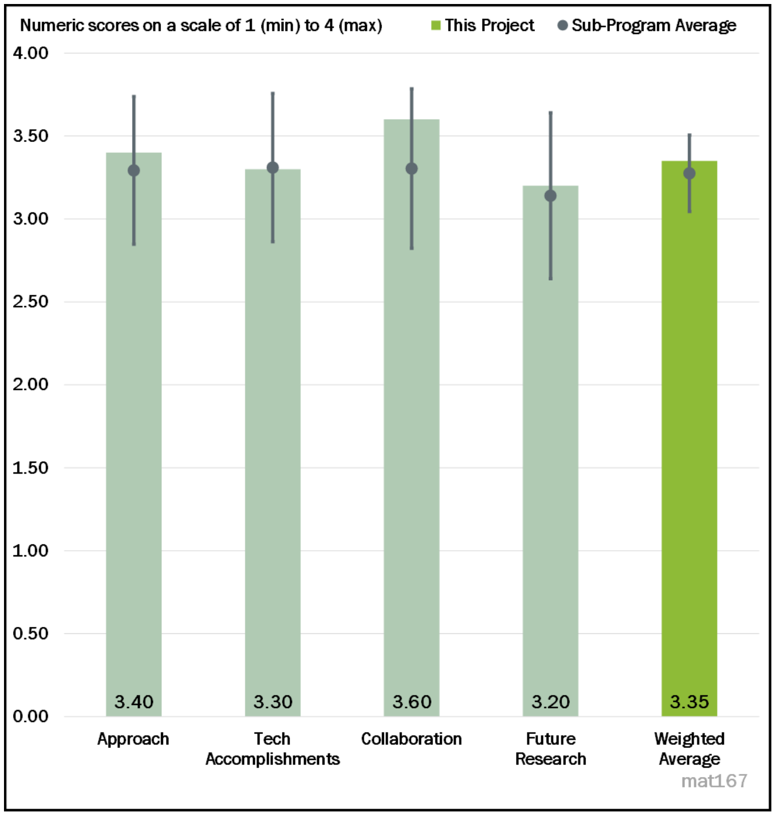

Figure 6-23 - Presentation Number: mat167 Presentation Title: Corrosion Mechanisms in Magnesium-Steel Dissimilar Joints Principal Investigator: Vineet Joshi (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The overall project approach seems well designed to support a better understanding and predictive modeling of corrosion mechanisms in multi-material (e.g., Mg-steel) dissimilar joints, both at the joint and away from the joint.

Reviewer 2:

The approach is good. Pacific Northwest National Laboratory’s (PNNL) joining competence and Oak Ridge National Laboratory’s (ORNL) evaluation capabilities are well integrated.

Reviewer 3:

This is a very fundamental approach to galvanic corrosion in a very commercially important system. It couples many state-of-the-art methods into a strong scientific plan. It is not well connected to industrial design practice and not fully clear if or how that gap would be bridged.

Reviewer 4:

The approaches were summarized in Slide 4, where the modeling and scanning electrochemical cell microscopy (SECCM) are supposed to guide the process optimization; however, there is no information regarding the links between these two components from the current work.

Reviewer 5:
The approach of multi-scale corrosion characterization is appropriate for the duration of the project. The deliverables are meaningful and feasible in the proposed timeframe. The biggest drawback is that this relatively short project is designed to evaluate a single set of magnesium (Mg)-steel alloys coupled together. Any alloying changes made would require revalidation of the model.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The technical work is excellent and state of the art. There is excellent coupling of microstructure and corrosion. A publication would be expected but is not noted in this presentation.

Reviewer 2:
The technical accomplishments thus far seem to be on time and well in line with supporting the overall project goals with good, meaningful results.

Reviewer 3:
The technical accomplishments are good.

Reviewer 4:
The results are interesting. The fundamentals or causes behind the corrosion phenomena, however, are not presented.

Reviewer 5:
The project accomplishments are on track. Both the simulation and experimental validation experiments are progressing well and with encouraging results. The COMSOL models are limited and have not been validated yet.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaborations between PNNL and ORNL are clearly stated in the presentation.

Reviewer 2:
The collaboration between the partners appears to be fluid and meaningful, with data and materials flowing between collaborators regularly.

Reviewer 3:
The collaborators are well coordinated so that work at each is complementary to the others' in meeting project goals.

Reviewer 4:
Team collaboration seems to be quite strong.

Reviewer 5:
It appears that the collaboration between the laboratories is ongoing.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The plan for future work looks very strong, and the development of design guidelines is particularly important.

Reviewer 2:
Proposed future work seems well designed to improve the understanding and predictive modeling of multi material (e.g., Mg-steel) joint galvanic corrosion mechanisms.

Reviewer 3:
Larger scale factors, such as joint configuration, may have more influences on the corrosion behavior than the local features or microstructures (the different points on the potentiodynamic curves did not indicate significant differences).

Reviewer 4:
The proposed future work covers the wrap up and transition of the current tasks but does not propose the ability to expand this project into a more universal framework that accommodates alloy changes.

Reviewer 5:
The future research is not articulated to ensure success. The scope includes understanding versus resolution or mitigation of a known joining application.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Joining very electrochemically active Mg to other metals is of primary importance in next generation, multi material vehicles.

Reviewer 2:
This project supports lightweighting technologies by joining dissimilar lightweight materials.

Reviewer 3:
This project directly supports Department of Energy (DOE) objectives for multi material systems.

Reviewer 4:
The project supports the overall DOE objectives by developing a knowledge base to understand the galvanic corrosion potential of multi material (e.g., Mg-steel) joints comparing Mg-bare steel and Mg-zinc (Zn) plated steel.

Reviewer 5:
Corrosion of multi material joints is core to the application of lightweight materials to realize energy efficiency objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
There appears to be an efficient use of resources for expensive and advanced experiments.

Reviewer 2:
The team is well prepared with the resources for the proposed work.

Reviewer 3:
The resources are sufficient for the project's stated milestones.

Reviewer 4:
Resources seem sufficient to achieve the stated milestones within the project timing.

Reviewer 5:
Resources are well balanced based on the budget.

Presentation Number: mat168
Presentation Title: Low-Cost Resin Technology for the Rapid Manufacture of High-Performance Reinforced Composites
Principal Investigator: Henry Sodano (Trimer Technologies, LLC)

Presenter

Henry Sodano, Trimer Technologies, LLC

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

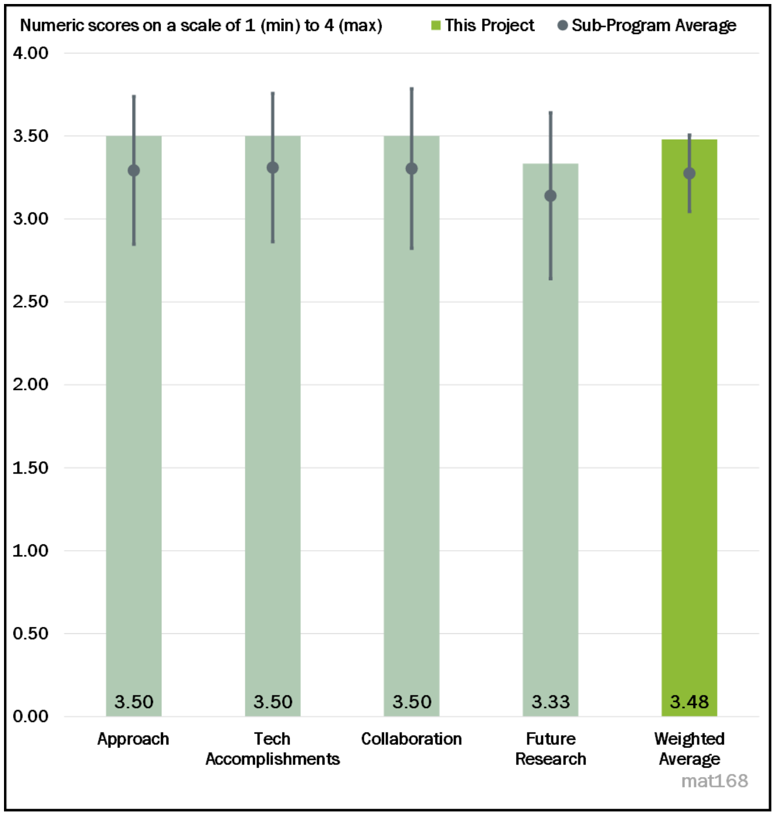

Figure 6-24 - Presentation Number: mat168 Presentation Title: Low-Cost Resin Technology for the Rapid Manufacture of High-Performance Reinforced Composites Principal Investigator: Henry Sodano (Trimer Technologies, LLC)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Trimer Technologies, LLC, developed a resin transfer molding (RTM) resin with both rapid cure and significantly improved mechanical properties. The approach is novel, and the results are encouraging.

Reviewer 2:

The approach uses a proprietary resin to overcome all the barriers and meet all technical targets. Because the primary technology (e.g., the resin) is proprietary, no information is presented on its composition or the cost, so addressing the DOE technical target of cost effective systems will need to be addressed for a full-scale system if the project is funded in Phase II. The project is well designed, and the results were obtained using a systematic approach of resin characterization, curing parameters, and molding characteristics. For a low budget, short term project, the results were impressive in meeting technical targets for potential high volume processing of carbon fiber composites in multi-layers and improved inherent resin-fiber bonding. An additional technical target for a fire retardant composite was achieved, although it is not a current DOE technical target for automotive materials.

Reviewer 3:

The project team listed several positive attributes of the resin system, such as:

- Low viscosity for rapid infusion

- Rapid cure
- High strength, stiffness, and toughness
- Nonflammable
- High glass transition temperature (Tg)
- Goals of reaching high pressure (HP) RTM cycle times.

However, there was really no basis to judge what the resin system or what chemistries are at play. While it is understood that some information may be proprietary, the reviewer indicated it was very difficult to make an assessment of the merits of the system with no basic idea of the chemistry and environmental implications. This was a main weakness.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
For a 1-year project, the results for a high strength polymer with a low viscosity for better wetting of the fibers and significantly reduced process cycle times were quite impressive. Resin properties for the Tg, tensile strength, modulus, strain, and compressive strength far exceeded the properties of other commercial resins, which indicates that the carbon fiber (CF) composites made with this resin have a high probability of meeting or exceeding DOE's end product goals for strength and modulus. The high viscosity at low temperatures and stable lower viscosity at higher temperatures for several minutes are good characteristics of a resin than can be used effectively in HP-RTM processes. The cure rates presented were significantly lower than typically experienced in production, which will certainly contribute to cost effective high volume processing. The lamination of several fiber layers produced reasonable strength results for a small sample. All milestones for the performance measures were met.

Reviewer 2:
Phase I has been very successful, with encouraging results and the potential to achieve a cycle time of 1 minute or less.

Reviewer 3:
The reviewer would like to reference prior comments from criterion B. On Slide 7 where the project team lists Trimer's resin, alongside systems such as Dow Chemical, Huntsman, AOC, and Reichhold, the Trimer values are significantly higher. While this is commendable, without a scientific basis, it is not possible to make a reasonable judgment. Looking at the slides, yes, the technical accomplishments and progress are excellent; however, as a scientific reviewer, the information presented is very spare to make a reasonable evaluation.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team consists of a resin manufacturer, a parts manufacturer, a composites manufacturing scale-up facility, and unnamed original equipment manufacturers (OEMs). Collaborative efforts appear to be well coordinated, with equal participation from all partners. Collaborations cover the full spectrum, from materials development to manufacturing.

Reviewer 2:
Trimer has been collaborating with the Institute for Advanced Composites Manufacturing Innovation (IACMI) Scale-up Research Facility (SuRF) and TPI Composites and plans to move to Phase II to advance to commercialization.

Reviewer 3:
The project team's collaboration with TPI and IACMI seems good. However, at this stage of the project it was not possible to determine the success or steps taken for this collaboration. Supposedly, that will emerge downstream in the project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The Phase I Small Business Innovation Research (SBIR) project has ended, but with the results from Phase I, there is a high probability that work will continue. The project has successfully progressed from a new resin material to small-scale testing of composites fabricated with the resin using a well-known commercial process. The proposed future research logically progresses to the involvement of Tier 1 suppliers and OEMs to assist with development of prototype scale processing parameters and characterization of the prototype parts. The presenter also addressed the coordination with OEMs to establish production tooling for specific applications, such as battery enclosures for electric vehicles (EVs).

Reviewer 2:
The proposed future work lays out a good pathway to continue the development of Trimer's HP-RTM, and the project team has already submitted a Phase II proposal.

Reviewer 3:
The proposed future work is both on the technical and commercial side. The project team is looking to expand process development and material testing with a goal of generating sufficient data toward commercialization. The team is looking toward process development, which necessitates rheology and kinetic studies, and will develop an internal mold release per the claim. Resin adoption in high volume automotive manufacturing requires scale-up of the manufacturing process. Component level testing will be required for commercialization. The team will develop relationships with OEMs based on the above. While these are reasonable, the vagueness of the information continues to occur when the team talks about future research. There is very little concrete information that could be gathered.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
If the technology successfully transfers to vehicle manufacturers, then the DOE goals for cost effective designs, high volume composites processing, joining of multi-materials, and lightweight structural automotive components will be met or exceeded.

Reviewer 2:
Trimer's resin has shown less than 1-minute cycle times. This is important for cost reduction for vehicle composite manufacturing.

Reviewer 3:
The project aims to reduce cycle times and provide resins with higher performance, which will benefit DOE's lightweighting goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
For a 1-year SBIR research effort, the funding and research companies involved were sufficient to meet the project milestones and goals in a timely fashion. Funding of $200,000 per year for characterizing the resin properties and small-scale testing was sufficient.

Reviewer 2:
Trimer has been working with IACMI-SuRF and TPI to leverage resources and has made progress in a timely manner.

Reviewer 3:
It was not possible to judge accurately on this, but it appears the team has the resources.

Presentation Number: mat169
Presentation Title: Short-Fiber Preform Technology for Automotive Part Production
Principal Investigator: Dirk Heider (Composites Automation, LLC)

Presenter

Dirk Heider, Composites Automation, LLC

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

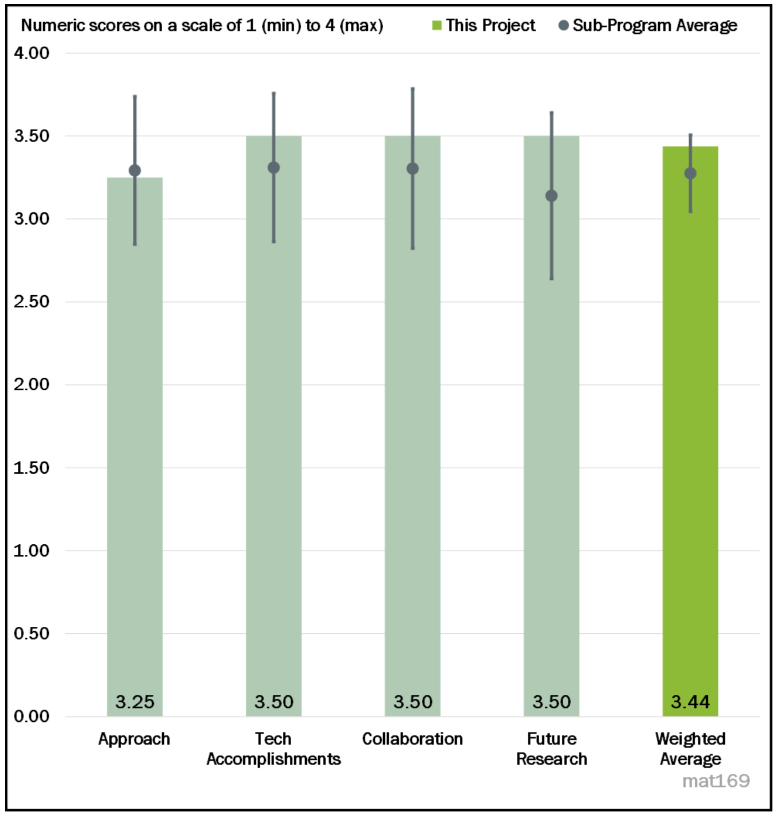

Figure 6-25 - Presentation Number: mat169 Presentation Title: Short-Fiber Preform Technology for Automotive Part Production Principal Investigator: Dirk Heider (Composites Automation, LLC)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Composites Automation uses tailored universal feedstock for forming (TuFF) to eliminate preforming challenges, allow the use of recycled fiber, and enable at-rate production and lower cost. This might lead to a paradigm shift in composite processing.

Reviewer 2:

The approach for using tailorable feedstock and forming to reduce the cost of raw materials through reuse of CF materials is effective and contributes to overcoming the DOE target of low cost, high production fiber feedstocks and composite preforms. The process described in the approach is attractive from the aspect of material recovery and reuse and minimal waste. Other technical barriers and DOE targets such as weight reduction, material properties for end products, and innovative architectures are not addressed by this very short (9 month) Small Business Technology Transfer (STTR) project. The survey of commercially available, low cost CF was not comprehensive, but was sufficient to compare TuFF technology with commercial materials, and the presenter indicated that discussions were started with major suppliers of CF and CF products.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

For the short period of performance, the progress presented for the tasks described in the project schedule Gantt chart on Slide 2 indicates very good technical accomplishments and project performance as measured against the performance indicators (milestones). A significant amount of aligned CF material was produced with consistent areal weight, which is a good feature for preform material. The evaluation of aerosol spray and veil materials for binders gave good technical results for the veil material, which is also a good approach for fabrication of preforms on a commercial scale. The evaluation of an electro-spun veil material showed a novel approach for improving and optimizing the manufacture of the final fiber product. Preliminary results for fiber strength and modulus show improved properties over a well-known commercial fiber, and projected even further improvement with an increase in the full volume fraction. The cost comparison was adequate to evaluate as-manufactured material costs. The costs did not directly relate to automotive component cost reductions of less than $5 per pound saved, but the presenter alludes to the fact that recycled fibers have the long-term potential to meet the DOE goal of less than $5 per pound for the base CF material.

Reviewer 2:

The team fabricated uni-directional, thin-ply CF sheet material and cross-ply CF preform material. Flat coupons were used for mechanical testing, and the preliminary results are encouraging.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This is a short term Phase I STTR project and should not be expected to have extensive collaboration with multiple partners. The collaboration was between a material developer and a university. Coordination between the two performers is good and well coordinated.

Reviewer 2:

The team collaborated with the University of Delaware and reached out to ORNL's Carbon Fiber Technology Facility (CFTF), Zoltek, and the SGL Group.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:

The proposed future research focuses on stabilizing the process, selecting an automotive part, testing the automotive part, and manufacturing cycle time and cost. This is a logical follow-on to the progress and accomplishments in Phase I and appears to be well planned. The company plans on working with manufacturers of resins and automotive parts to transfer the technology to OEMs. Risks are not addressed, but this is mostly process development which has fewer and lower risks than material development.

Reviewer 2:

The team lays out a very good pathway to move to Phase II to advance to commercialization.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The technology and process development presented supports the overall DOE objective for low cost, high production fiber feedstocks to meet the needs of the automotive industry. Other DOE requirements and targets for end-product material performance and production volume were not addressed at this stage of research but should be addressed if the proposed future research is funded and executed according to the project plan.

Reviewer 2:
The TuFF process has demonstrated capabilities for net shape preforming and reuse of fiber waste.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
For the very short performance period (9 months), the funding level is sufficient for the two agencies conducting the research. Additionally, the presenter indicated that the TuFF material was initially developed under a Defense Advanced Research Projects Agency (DARPA) program, so much of the early research on the technology was already funded and testing, requiring minimal resources.

Reviewer 2:
The team used the resources of Composites Automation and University of Delaware and reached out to ORNL CFTF, Zoltek, and SGL.

Presentation Number: mat170
Presentation Title: Embedded Networked Elements for Resin Visualization and Evaluation (NERVE) System for Intelligent Manufacturing of Multifunctional Composites for Vehicles
Principal Investigator: Amrita Kumar (Acellent Technologies, Inc.)

Presenter

Amrita Kumar, Acellent Technologies, Inc.

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

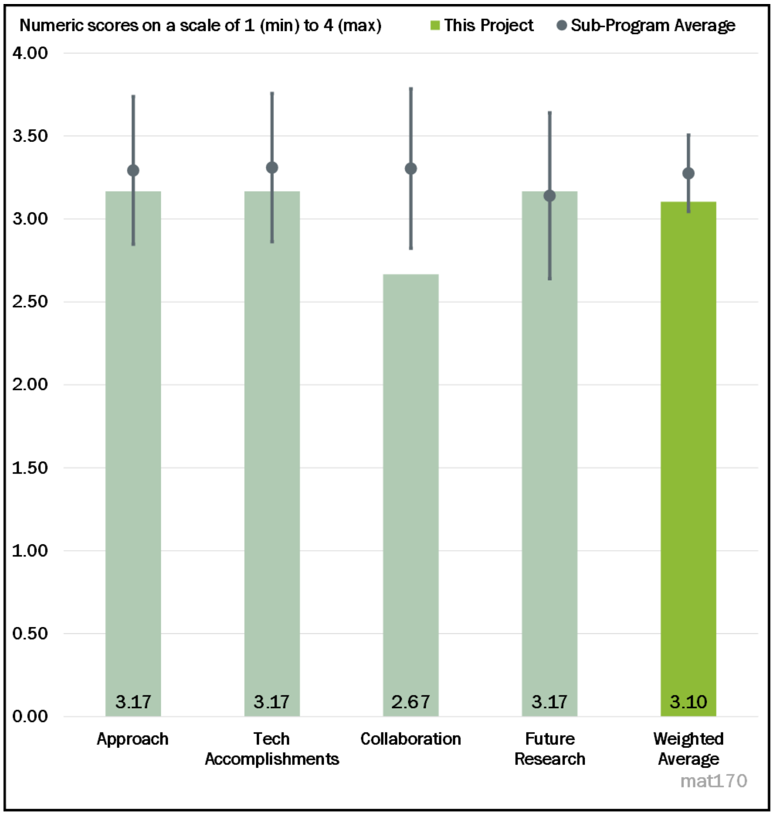

Figure 6-26 - Presentation Number: mat170 Presentation Title: Embedded Networked Elements for Resin Visualization and Evaluation (NERVE) System for Intelligent Manufacturing of Multifunctional Composites for Vehicles Principal Investigator: Amrita Kum

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The team has demonstrated a Networked Elements for Resin Visualization and Evaluation (NERVE) system consisting of embedded actuating and sensing elements to monitor and enhance all phases of the composite manufacturing process used in the automotive manufacturing industry. The NERVE system may find applications in composite structure health monitoring.

Reviewer 2:

While the approach of embedding piezoelectric sensors in composite laminates is not entirely new, there is prior work on this (see the Smart Materials & Structures Journal, SMARTweave at the Army Research Laboratory, and other related works), the work is very thorough and practical for implementation in real manufacturing. The approach is to conduct proof of feasibility during manufacture and measuring the sensor response over a period of time.

Reviewer 3:

The approach focuses on the technical feasibility but not on the robustness, costs, or other aspects of the systems.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The team has demonstrated good sensitivity and selectivity of the NERVE system. Phase I has been very successful.

Reviewer 2:
In the initial work, the team has demonstrated embedding a smart piezoelectric sensor in a composite laminate. The team developed a curing algorithm to accurately predict the onset and progression of the cure. The tool also went on to be used for damage detection. The team claims a reduced manufacturing time of about 30% from the data obtained from the sensor. Items that were not entirely clear to this reviewer include the following: material systems; laminate thickness; locations of the sensor (and if this is a factor in the sensitivity); and amount of complexity in accessing the sensor during manufacturing. These are factors that would influence manufacturing ability. Supposedly, these will be considered as the project progresses.

Reviewer 3:
There are solid technical accomplishments but no mention of the return on investment (ROI) that was claimed to have been accomplished.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration between Acellent and the University of Delaware was excellent, and the team plans to apply for Phase II to continue the development of the NERVE system to advance it to commercialization.

Reviewer 2:
At this stage of the project, it was not entirely clear what the University of Delaware is doing, or if all the work is being performed there and the company is primarily providing the sensor and conducting data analysis. However, this may get more streamlined as the project progresses. Bavarian Motors Works (BMW) and Armor Works have been identified as collaborators. It was not clear what their role was or is going to be as the project progresses.

Reviewer 3:
While the University of Delaware was mentioned and credited, the division of tasks, the roles and responsibilities, and the types and frequency of the interactions were not mentioned.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The project has well defined decision points with go/no go. The Phase I has demonstrated feasibility and results are encouraging for moving to Phase II.

Reviewer 2:
The project team's progression to the next steps are logical. The team will evaluate the sensors both in the laminate and the tool. No details are known about the sensor integration in the tool— location, type of tooling (steel, Al, non-metallic?), number of sensors, hardware access, etc. These will all play a role in the practical utilization of these sensors. Also, the reviewer wanted to know if the sensors are only limited to autoclaves or how do the sensors offer many process options. If that is not a restriction, that must be somehow articulated to demonstrate wider utilization.

Reviewer 3:
The proposed future work is for the (currently unfunded?) subsequent phase. The efforts to ramp up to pilot scale and prove the technology in a manufacturing environment is appropriate. The reviewer hoped that the future phases will have technical cost modeling to more effectively gauge the value of the developments.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The NERVE system has the demonstrated capabilities of optimizing the composite manufacturing process; improving manufacturing quality; increasing throughput by optimizing production rate; eliminating the need to scrap components due to poor quality; and reducing overall costs by eliminating time consuming, post fabrication inspections leading to high volume production use in automotive industries.

Reviewer 2:
Improvements in the manufacturing of composites will likely reduce the costs barrier for automotive OEMs to reduce weight.

Reviewer 3:
The key finding is the reduction of manufacturing time, which the team claims is about 30%. If so, there are cost and energy saving implications which are of importance to DOE. While the team demonstrates the sensor in an infusion type of process, DOE relevance may also need information for processes like fast compression molding and pre-preg stamping for high rate processes. Will the sensors survive those types of automotive relevant processes, or are the sensors limited to liquid molding only?

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The team used the facilities at both Acellent and the University of Delaware to advance the project in a timely manner.

Reviewer 2:
Resources are sufficient.

Reviewer 3:
It was not clear what resources are at the company, and how much is being leveraged from the University of Delaware. Overall, the team seems to have the resources to execute the work.

Presentation Number: mat171
Presentation Title: Discontinuous Low-Cost Carbon Fiber/Bamboo Fiber Hybrid Intermediates for Lightweighting Vehicle Applications
Principal Investigator: David Knight (Resource Fiber, LLC)

Presenter

Lee Slaven, Resource Fiber, LLC

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

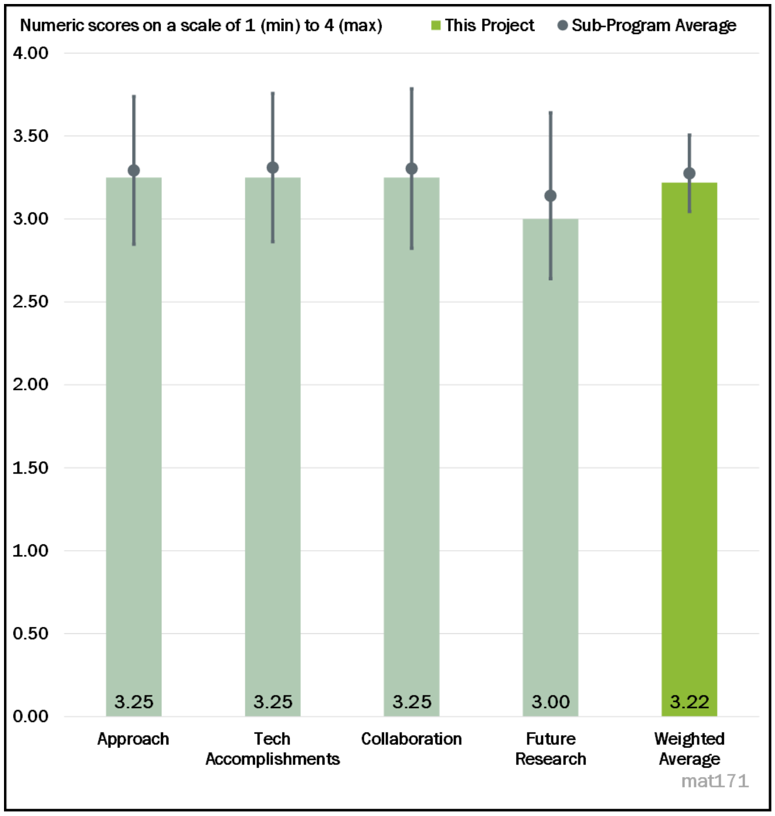

Figure 6-27 - Presentation Number: mat171 Presentation Title: Discontinuous Low-Cost Carbon Fiber/Bamboo Fiber Hybrid Intermediates for Lightweighting Vehicle Applications Principal Investigator: David Knight (Resource Fiber, LLC)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The team used hybrid bamboo fibers and CFs to reinforce polypropylene (PP). This is very creative. The approach is novel and the results are solid and of great interest. The composite cost is reduced by using less CF.

Reviewer 2:

There is a good design of experiments approach to this proof of concept study.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The project is on track and in good shape. The team works on the remaining milestone (which is delayed due to COVID-19,) with the hope to wrap up the project by the end of June 2020.

Reviewer 2:

Testing was complete and detailed. The reviewer had hoped to see the error bars, number of samples, and other details that would speak to the robustness of these material test results.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration was excellent between Resource Fiber, the University of Tennessee at Knoxville (UTK), and IACMI.

Reviewer 2:
Good results usually result from good cooperation. This presentation does not mention division of tasks, roles and responsibilities, and the frequency of meetings.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The team plans to extend the research to Phase II to advance to commercialization.

Reviewer 2:
The project has ended. The future challenges for a potential Phase II project have been identified. However, there needs to be technical cost modeling to ascertain the value of any developments.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
CFs are expensive for vehicle applications. The team used bamboo fibers to reduce CFs, which is quite novel.

Reviewer 2:
Reducing the costs of high performance composites will lead to lighter weight vehicles.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The team used all possible resources and made progress to the overall objective. Due to COVID-19, the last milestone was delayed.

Reviewer 2:
Resources are sufficient.

Presentation Number: mat172
Presentation Title: High-Performance Fiber-Reinforced Vitrimer Composites through Compression Molding
Principal Investigator: Yinghua Jin (NCO Technologies, LLC)

Presenter

Yinghua Jin, NCO Technologies, LLC

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

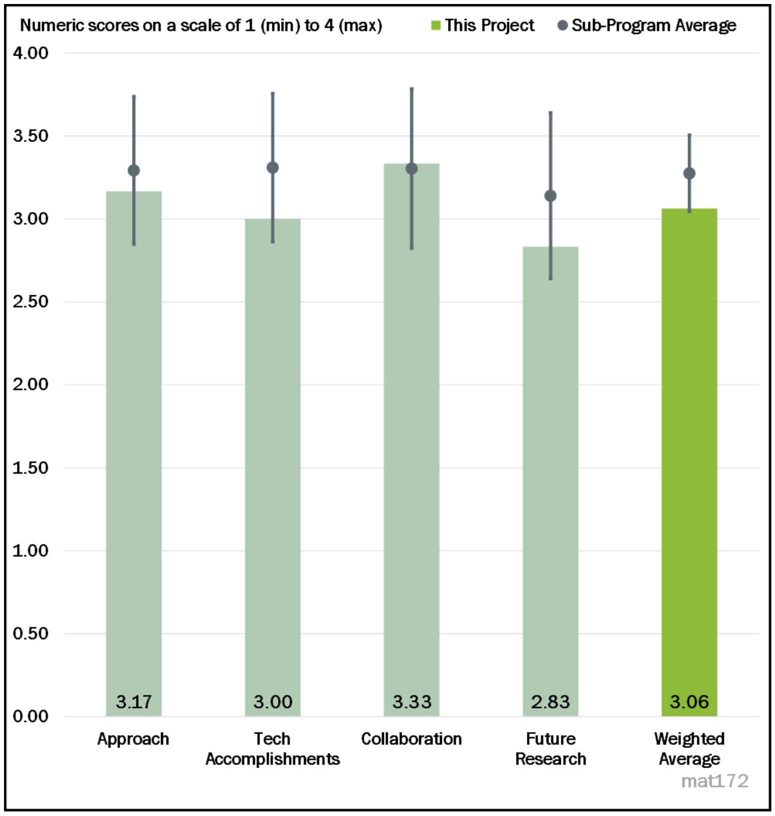

Figure 6-28 - Presentation Number: mat172 Presentation Title: High-Performance Fiber-Reinforced Vitrimer Composites through Compression Molding Principal Investigator: Yinghua Jin

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The use of vitrimers as polymer binders in carbon fiber reinforced composites (CFRCs) is novel and may find more applications in other polymer composites. The results from recycling CFRCs are very useful. The reviewer appreciated the closed loop approach.

Reviewer 2:

The project team proposed a reversible resin chemistry via vitrimers in the approach. The team aims to achieve fast bond exchange reactions at an elevated temperature to enable vitrimer particle fusion and interface healing through bond exchange reactions during compression molding, as well as depolymerizing the polymer matrix by upsetting the stoichiometry of the end groups at the end of product life. Overall, the approach has merit, but there was very little by way of the system chemistries to make an evaluation of scientific merit.

Reviewer 3:

The team has a good approach to this initial study on vitrimer composites with CF. The approach could have been improved with more span to the studies on gauge (perhaps 1-5 mm thickness and different types of CF composites).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The team has demonstrated fast-moldable vitrimers with good mechanical and thermal properties. The fast compression molding technique to form CFRCs was done in a short processing time of 2-3 minutes. This is a big deal in CFRC manufacturing.

Reviewer 2:
The team has proven the initial concept of this technology. The compression molding was accomplished. The progress would have been more substantial if the number of recycling and reprocessing attempts had been investigated and reported. The reviewer was curious as to what happens as over 95% of the vitrimer and CF composites is reused 10, 20, or 100 times.

Reviewer 3:
Some of the comments made under Quarter 2 (Q2) apply here as well. For example, on Slide 6, the team calls out vitrimer 1 and vitrimer 2 without providing any context of what these are or what the differences in these systems are. The reviewer wanted to know what are the relative viscosities of the system, processing issues, and parameters of any of these? Slide 7 has similar issues and it was not clear how the team is processing the vitrimers with the carbon fabric (sheet, film, bulk?) and how the team is ensuring good dispersion. While some of this information may be proprietary, as a reviewer, there was no basis to make an objective statement.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration between NCO Technologies, LLC, and the University of Colorado at Boulder to advance the project was excellent.

Reviewer 2:
There is a clear division of tasks. The reviewer would like to know how often joint meetings were conducted and if any team members were collocated.

Reviewer 3:
The work is in its early stages. The collaboration with the University of Colorado at Boulder should expand in the coming periods. Also, the roles of who did what was not clear. The results thus far are very laboratory scale and seem to be generated at the university.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The team has demonstrated many encouraging results, and the vitrimers should find more applications in vehicle structures. The project lays out pathways to future studies. Although the principal investigator (PI) mentioned that the team was not going to apply for Phase II, the team may seek industry and other funding sources for future work.

Reviewer 2:
Future work would be enhanced with a technical cost model to ascertain the value of this technology.

Reviewer 3:
The team plans to continue working on the development of the vitrimers and reduce processing times and will also evaluate reprocessing, weldability, and repair. These are good goals, but it would be good to first see

robust laminates and laminate data before going on to these steps. The chemistry optimization seems to be needed first, or at least was not presented here for a meaningful review.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Vitrimers are novel, malleable thermosets with many distinct advantages that would offer significant environmental and economic benefits. The team is encouraged to do more fundamental research and advance to commercialization.

Reviewer 2:
DOE is looking at various technologies for recycling of its systems, and this work has the potential for this in the long term. The work is still very early stage.

Reviewer 3:
This could reduce the mass of parts in cars and trucks to improve fuel economy.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The team uses the resources from both NCO Technologies and the University of Colorado at Boulder, making progress toward the objectives.

Reviewer 2:
There are sufficient resources for this initial study.

Reviewer 3:
It was not clear who has what, but the team seems to have the resources for conducting the work. Work definitions need to be lot clearer.

Presentation Number: mat173
Presentation Title: Self-Sensing Fiber-Reinforced Composites
Principal Investigator: Christopher Bowland (Oak Ridge National Laboratory)

Presenter

Christopher Bowland, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

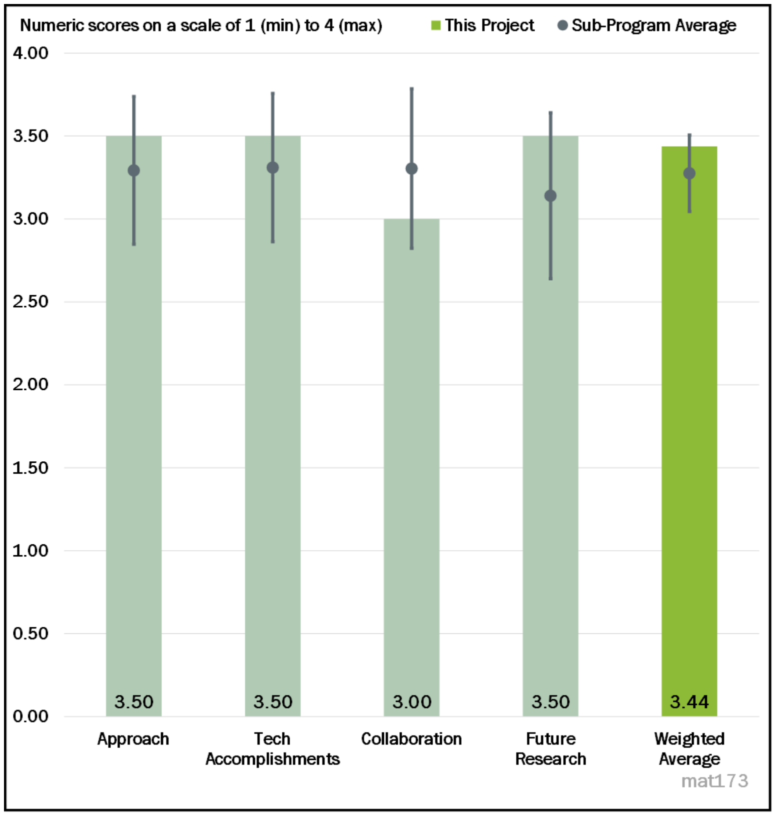

Figure 6-29 - Presentation Number: mat173 Presentation Title: Self-Sensing Fiber-Reinforced Composites Principal Investigator: Christopher Bowland (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer appreciated the approach taken by the research team using titanium dioxide (TiO_2) nanoparticles to demonstrate “roll-to-roll” processing and results through thickness sensor performance as a function of applied strain. With the additional benefit of excellent surface dispersion and improved interlaminar shear properties demonstrated, there is a compelling argument to pursue this course. Well done.

It would have been helpful to better understand the approach planned (by schematic, identification of potential hardware, or simple description) by the team to pursue wireless applications. The use of drones to perform autonomous inspections is very attractive for other critical infrastructure (for example, wind turbines).

Reviewer 2:

By using a roll-to-roll fiber processing method to add various nanoparticles to the fiber surface, the project is able to produce a multifunctional composite with structural health monitoring capabilities. Structural health monitoring would help inform models for in-service performance prediction and would allow for an optimized design while minimizing cost.

Reviewer 3:

The approach is very innovative in creating a fiber sensing capability by deposition of nanoparticles on the fiber surface. This is a new project, and this was the first review of this project. The team investigated a roll-to-roll dip coating deposition process to integrate nanoparticles into the sizing for improved mechanical strength and sensing functionality.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
As the reviewer suggested in prior comments, the progress shown by this team in a year's effort (for the dollars expended) is quite good. The improvement in transverse shear properties is quite significant, and the progress to demonstrate the potential capability to work as an active strain sensor is similarly important and demonstrates outstanding progress.

Reviewer 2:
The multifunctional composite produced is shown to have a 14.7% increase in interlaminar shear strength (ILSS) and a maximum gauge factor increase of 187%.

Reviewer 3:
The initial results seem promising. The team demonstrated a 14% improvement in ILSS with just 1% nanoparticle loading. Also, the gauge factor was seen to increase by 187% with 2.5% weight nanoparticles.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
While the reviewer had no explicit criticism of the research team, the project progress reported would seem to be the result of the ORNL research effort and the collaboration of interns (commendable as well) working on the ORNL campus. It is not clear how Dronesat, LLC, will participate in the research effort. There appears to be a straight line connection between the success of the fiber sensor as a wireless communication element in a structural health monitoring application that is performed by drones, but the reporting does not provide a complete picture of how or when Dronesat participates. Clearly, the results and progress speak well of the operation of the research team.

Reviewer 2:
The collaboration with Dronesat has offered the research product (multifunctional composite) a great platform for demonstration of its capability and benefit.

Reviewer 3:
The collaboration with Dronesat is not entirely clear. Perhaps that aspect will shape up later in the project. The work is primarily conducted at ORNL at this stage.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The team's proposed future work is logical and in line with the work. The team plans to coat fibers with ferroelectric nanoparticles, measure electrical and mechanical properties, evaluate wireless sensing, reinforce thermoplastic matrices with passive sensing fibers, and evaluate hybrid composites and passive sensing composites. These are reasonable future tasks.

Reviewer 2:
The research team did an excellent job of describing the upcoming work in pivoting from the TiO_2 nanoparticles to barium titanate ($BaTiO_3$) to create a passive sensor capability. The step associated with this proposed work is well described and appears feasible and attainable. The reviewer would simply liked to have seen a bit more detail regarding plans to create a wireless communication capability.

Reviewer 3:
Passive sensing with wireless communication will enable monitoring of in-service degradation of materials and will increase composite safety or provide an estimation of maintenance requirements. Since many materials are subject to cyclic loading in service, it would be good to have some data on the impact of the new fiber coating on the fatigue of the composites.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
DOE has clearly expressed the importance of expanding the use of high specific strength and stiffness materials (i.e., CFRPs). The advancement of effective condition monitoring technologies that improve structural reliability and provide insight into condition will allow for higher levels of user confidence and will expand utilization. That supports this goal and will ensure a continued trend of lightweighting of transportation systems.

Reviewer 2:
Multifunctional materials will enable a wide application of composites, especially in some special applications where material electrical conductivities and/or in-service integration is critical. That will contribute to DOE VTO lightweight objectives.

Reviewer 3:
The work aligns with DOE goals of creating multi-scale, multifunctional composites that have an overall lower carbon footprint. The future of this work is leading to that goal.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The funding level is quite modest, but the work performed and progress reported suggest that the resources are sufficient. The reviewer was curious about whether additional funding to support specific real applications should be considered at the conclusion of this foundational work.

Reviewer 2:
The project is achieving its objective.

Reviewer 3:
The team has adequate and high-quality resources through the Manufacturing Demonstration Facility (MDF) at ORNL and through partners.

Presentation Number: mat174
Presentation Title: Carbon-Fiber Technology Facility (CFTF)
Principal Investigator: Merlin Theodore (Oak Ridge National Laboratory)

Presenter

Merlin Theodore, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers indicated that the resources were sufficient, 33% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

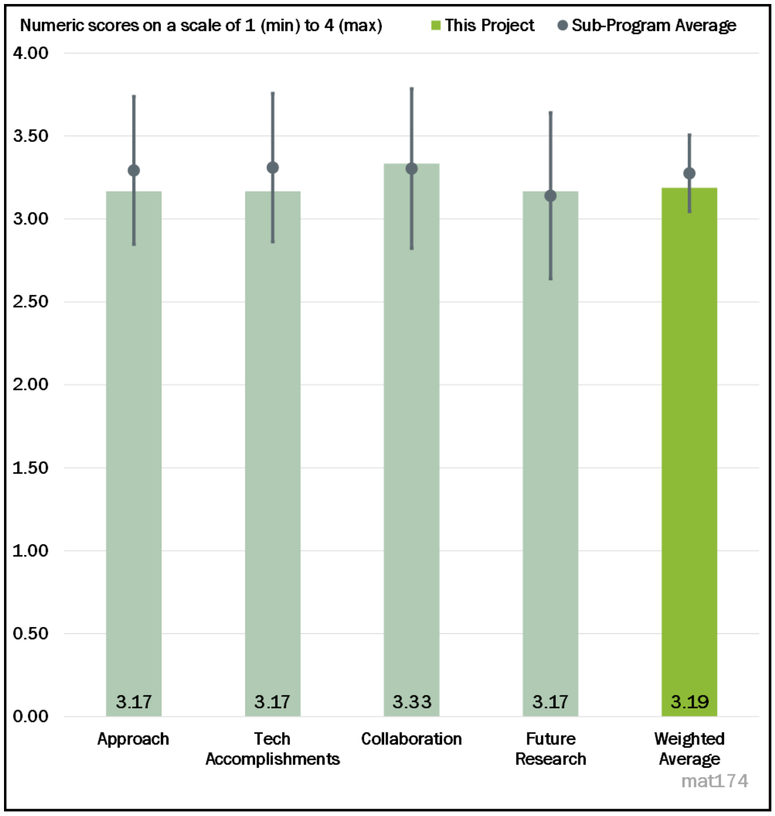

Figure 6-30 - Presentation Number: mat174 Presentation Title: Carbon-Fiber Technology Facility (CFTF) Principal Investigator: Merlin Theodore (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The CFTF has been very successful. It has served as an incubator for scaling up new precursors and conversion processes. Such an approach helps remove the barriers in advancing commercialization of low cost, high performance CFs.

Reviewer 2:

The broader mission of the CFTF is not clearly delineated from the specific VTO project work. The reviewer’s takeaway is that VTO funding supports the activity with mesophase pitch precursors. The effort is to work with three of five candidate materials, but it would be helpful, and improve the quality of the research, if a more explicit plan is included to interrogate other properties of the resulting blown fiber mats (including nominal fiber diameter, variance in fiber diameter, specific gravity, modulus, etc.). Finally, it is not clear if conversion to structural materials (via impregnation and cure) is planned, and more importantly, followed by testing and evaluation of those resulting composites. It is also not clear whether a path toward aligned fiber reinforcements using these candidate (or down-selected) precursors is being planned. Iit also seems important to seek out useful molecular models that can inform or predict process parameters and resulting properties to support a more rapid screening and drive future of mesophase pitch selections and designs.

Reviewer 3:
Manufacturing of carbon composites using pitch showcases the capability of the CFTF. However, it does not clearly demonstrate the facility's capability in terms of the barriers the project addressed, i.e., the cost of manufacturing, process validation and technology scalability, etc.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The team has extended the capability from polyacrylonitrile (PAN)-based pilot runs to pitch-based CFs. The CFTF has been helping academia and industry research and development (R&D) validate the recipes and scale-up.

Reviewer 2:
The team has successfully melt-blown pitch material from various sources. During blowing, multiple spinning conditions were tested, based on initial conditions suggested from rheology. Researchers demonstrated a full year of operations with zero accidents or environmental non-compliance.

Reviewer 3:
Progress includes a lot of regulatory hurdles, which the reviewer understood is necessary and meaningful, but less than technically significant. The accomplishments related to melt-blowing three of the five candidate precursors demonstrate important progress but leave many of the challenges and barriers in place and do not answer important questions related to the cost of the resulting fiber. Similarly, the referenced disadvantage vis-a-vis PAN precursors, strain to failure, and tensile strength has not been addressed as part of this year's technical accomplishments. The reviewer could not assess whether the results are promising or not.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration between the CFTF, academia, and industry partners has been going well. The CFTF has been reaching out to potential collaborators to make more impact.

Reviewer 2:
The project is very impressive, especially the collaboration between the ORNL teams: working with the analysis group on a multi-scale approach to develop optimal mechanical properties of the resultant CF from alternative precursors and working with the thermal analysis group on thermal properties.

Reviewer 3:
There is little offered that demonstrates how the collaboration (whether through the IACMI partnership or other noted collaborators) impacted the technical approach or accomplishments. It would be helpful to understand what market drivers, technical performance parameters, or specific cost targets come from the end-users or collaborators.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The team lays out a solid future plan. The proposed future research makes sense and the research on pitch is of great interest and is making progress toward the set milestones. The project has a thoughtful pathway to mitigating risks and removing the barriers in the way to advance scale-up and commercialization.

Reviewer 2:
The proposed future research is clearly necessary, and those specific steps make sense to the reviewer. What does not make sense is the order in which the proposed work is presented. It seems that establishing criteria should come before efforts to increase throughput, take "in situ measurements," etc. It would also be more compelling if the research team proposed specific interrogation of the produced materials in the application that is most impactful for these materials, that is, as a reinforcing element in a structural composite. No material testing is proposed toward that end.

Reviewer 3:
Completion of the pitch-based CF trial can demonstrate the capability of the facility and is important. If some new precursors and technology could be tried using the facility, it would better show the facility's capability in terms of the barriers that the project addressed, i.e., manufacturing cost, process validation, technology scalability, etc.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
There is no question that the mission of the CFTF and the specific work to identify alternative, low cost mesophase pitch precursors is well aligned with the stated DOE objectives. This is important work and addresses the need for affordable materials for lightweighting of future transportation systems.

Reviewer 2:
The CFTF's research activities underpin and support the overall DOE mission and, in particular, VTO objectives. The collaboration with academia and industry opens up new opportunities for scaling-up and advancing commercialization of low cost, high performance CFs.

Reviewer 3:
The facility will help speed up the development of high quality and low cost CF composites and will contribute to using lightweight materials in vehicles.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The CFTF has been extended the capability from PAN-based CFs to pitch and other alternative CFs. Such enhanced resources facilitate the scaling-up via pilot runs at the CFTF. Additionally, the CFTF leverages resources via the partnership with academia and industry.

Reviewer 2:
The facility is well equipped.

Reviewer 3:
The reviewer remarked that resources are insufficient based on the lack of progress in identifying specific work to address challenges and barriers as presented by the research team. The proposed work does not appear to address the specific concerns ("challenges and barriers") related to "availability" and "quality" of mesophase pitch feedstocks. If the goal is to produce high performance (meaning high specific stiffness and strength) materials, make sure the work being planned provides an accurate view of the status and performance of the production materials.

Presentation Number: mat175
Presentation Title: Novel Materials for Polymer Composite Engine Blocks
Principal Investigator: Amit Naskar (Oak Ridge National Laboratory)

Presenter

Amit Naskar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers indicated that the resources were sufficient, 25% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

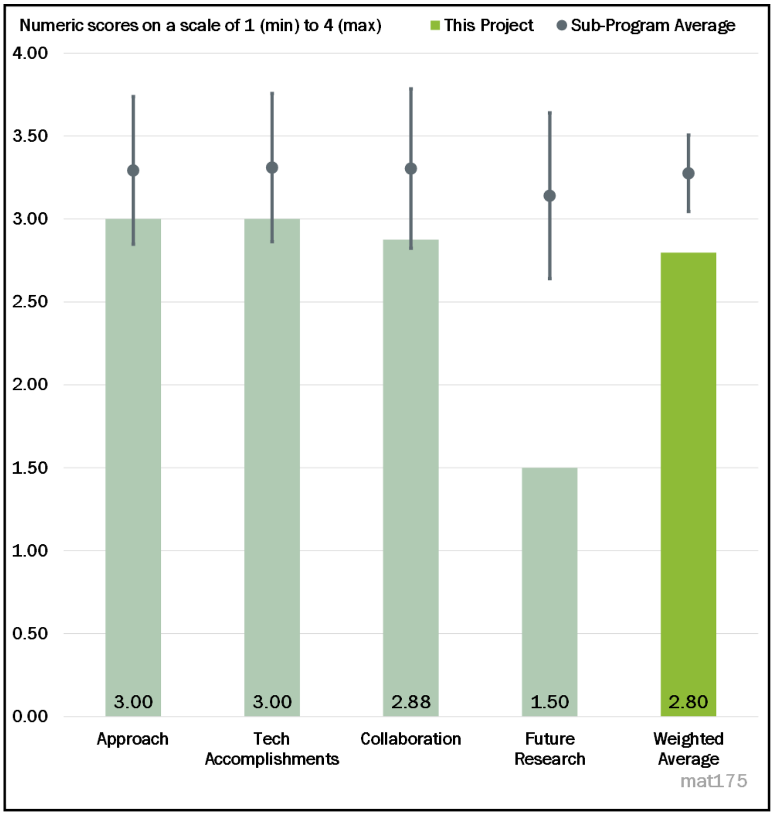

Figure 6-31 - Presentation Number: mat175 Presentation Title: Novel Materials for Polymer Composite Engine Blocks Principal Investigator: Amit Naskar (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project approach appeared rational for a specific element of a larger, five-thrust program. This project was relatively narrowly designed to address a single need: development of an affordable novel polymer matrix composite with satisfactory performance for light-duty (LD) engine block applications. The overall approach regarding different chemical compositions for the base composite, as well as structural reinforcement options and bonding agents, seemed logical.

Reviewer 2:

The “co-continuous toughened resin” makes sense for toughening the composite materials.

Reviewer 3:

Overall, this is an interesting project. As a novel approach to the deployment of a new material system, however, the presentation of results was hampered to some extent by the lack of a direct correlation to common materials in engine blocks. With the stated application known at the outset of the project, the specific opportunities and potential pitfalls are lacking and were addressed in a very general state on the “Relevance” slide. More detail in this area is appropriate for work that is considered exploratory.

Reviewer 4:

It is not explained in either the presentation or the documentation why “vehicle (engine) light-weighting” would be considered a barrier. Does the project team expect the polymer blocks to be heavier? The density of Bakelite is about half that of Al, so this seems very confusing.

The resin should also have noise dampening properties superior to Al; this is not referenced but is a positive attribute of the material with data rather than just a line on the Relevance slide. Common properties from the literature would have added value to the audience. Also, on the Relevance slide, the team states “Identify technology, cost and manufacturing challenges and opportunities.” However, the reviewer saw no further reference to cost in the presentation, other than stating the phenolic resins are “expensive.” This really needs data as to how expensive. Once again, literature data would add a lot of value.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project achieved both of its planned technical milestones. There is a concern, however, that the project approach called for identifying cost challenges, but there was little discussion in the presentation concerning cost. When questioned, the PI indicated that the expected cost of the material would be less than $4 per pound, but that improved joining with Al would be required (implying that this might not be the ultimate cost). The PI further indicated (in response to the full question which actually asked about relative cost-competitiveness) that he could not comment on cost-effectiveness without a scaled-up investigation. Therefore, to this reviewer, that appeared to be a shortcoming, despite the accomplishment of the other project goals.

Reviewer 2:
The project achieved reasonable strength and high temperature stability.

Reviewer 3:
The microstructure-properties-performance was not necessarily completed in this project. A more application-specific milestone would have been extremely valuable to the overall study, despite its rather short timeframe, such as a cursory study of fatigue behavior at slightly elevated temperatures. Clearly, this can be a topic for future exploration, but ultimately the study was simply a correlation between several different composites and tensile strength. It could have been for any application. Delving a bit further into the engine block potential (even if only in principle) would have added a great deal of merit to the study. The development of a new interfacial engineering method was claimed, but not described in any detail. Clearly, there was a small matrix of different composites being evaluated, but what novel approach was developed is not clear from the poster.

Reviewer 4:
There are several issues previously discussed that were raised in the introduction but never explained in the presentation. The work on the acrylonitrile butadiene lignin (ABL) resin does not say if it is more economically attractive than commercial resins, although it is implied this is the case by the first bullet point on Slide 5. The ABL plus CF plus trifunctional linker (TL) tensile strength is comparable to a 356 Al (A356); this would have been great to add to the slide for reference. The mechanical properties are interesting but should have been measured at temperature (100°C, for example) to show a direct application. It would have been helpful to include a simple paper study on the carbon impact of a resin block versus Al, which is very energy intensive.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration must have been good, as the stated milestones were achieved. The role of Michigan State University is somewhat confusing, and the reviewer would like to have known what exactly was scaled up. It would appear that the results are based on labscale testing and microstructures of test specimens. Regardless, the findings being presented show a high quality set of results, both from a characterization and mechanical properties analysis standpoint. How the work was divided is not critical; the work being presented shows the proposed level of progress.

Reviewer 2:
The project was led by ORNL, with assistance from Michigan State University's SuRF to conduct the full-scale testing. The University of Tennessee is also on the team; this was due to a post-doctoral candidate who donated his hours. Overall, this was a relatively small team assembled for a tightly scoped project.

Reviewer 3:
The collaboration seems good from the project results, but it is not described in the poster presentation.

Reviewer 4:
There is no evidence that the team was or was not communicating well between members.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
Proposed future research is not applicable in this case, but there is a great deal of work that can be done in this area that addresses the application-specific shortcomings of an exploratory project.

Reviewer 2:
Given this is a 1-year project, that does not preclude the team from discussing the possible future of this technology and the things necessary to move this forward.

Reviewer 3:
The project has ended. The PI indicated that a scale-up project would be required, but that a partner has not been identified.

Reviewer 4:
There was no proposed future work.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project was focused on reducing vehicle weight while at least maintaining (if not improving) performance. Success would result in more fuel efficient vehicles, in line with DOE VTO objectives.

Reviewer 2:
Polymer composites are a potential lightweight engine material.

Reviewer 3:
The qualification and deployment of a new materials system in major engine components (in this case, composites) is still not a practical reality, but studies like this that show the promise are important. A great deal of work is left to be done.

Reviewer 4:
This is an interesting initiative and should have a more materials-based focus.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The team successfully met its objectives and apparently did so ahead of schedule. Overall, this is a very good reflection on the team and its efforts.

Reviewer 2:
There was no indication that the limitations of the team on this work were caused by budget or resources.

Reviewer 3:
This project achieved its goal of toughening polymer composites for automotive engine applications. It reported reasonable tensile strength and temperature stability, but did not report ductility, toughness, or modulus, which would be needed for engine materials. More resources would be needed to provide a more complete answer to the challenges of polymer composites for automotive engines.

Reviewer 4:
The project has been completed.

Presentation Number: mat176
Presentation Title: Advanced Anticorrosion Coatings on Lightweight Magnesium Alloys by Atmospheric CO2 Plasma Treatment
Principal Investigator: Gyoung Gug-Jang (Oak Ridge National Laboratory)

Presenter

Gyoung Gug-Jang, Oak Ridge National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

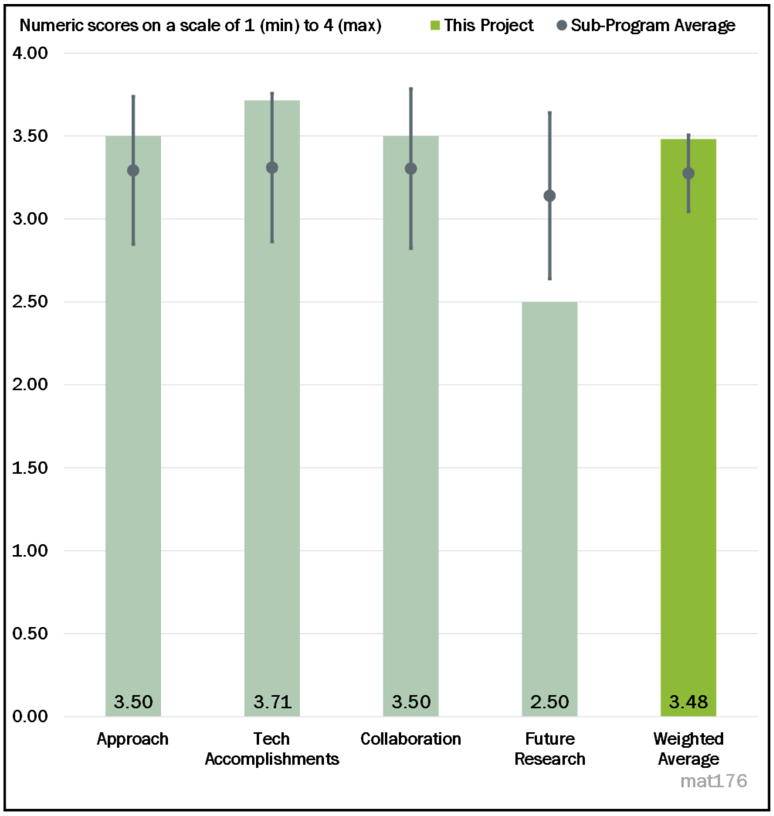

Figure 6-32 - Presentation Number: mat176 Presentation Title: Advanced Anticorrosion Coatings on Lightweight Magnesium Alloys by Atmospheric CO2 Plasma Treatment Principal Investigator: Gyoung Gug-Jang (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This 1-year project sought to develop a cost-effective anti-corrosion treatment for Mg using room temperature CO_2 plasma. The treatment that ORNL developed forms a superhydrophobic, nano and micro-structured surface layer, which mitigates saltwater attack. This project appears to have been well planned, designed, and executed (particularly for the short 1-year project timeframe), and achieved all milestones. Generally, it was very well done. The new coating system appears to be promising in addressing the main barrier for Mg, which is corrosion. The protect team made no comment as to how this new coating technology might affect other identified barriers for Mg (maintenance, repairability, recycling).

Reviewer 2:

This project falls under Subtask 5A of the Powertrain Materials Core Program (PMCP) in Research Thrust Area 5—Exploratory research. The approach used to investigate the impacts of many different materials for powertrain use in the PMCP is an excellent approach to use. This limits the commitment of government funding with a firm end to the project after 1 year. By completing the project in 1 year, DOE can perform the assessment of potential materials using this cost effective approach. Where applicable, other research programs should consider replicating this approach.

The project was a 1-year assessment, completed March 2020. DOE's share of this project was $150,000, and there was a cost share of $7,500 by Atmospheric Plasma Solutions (APS). All milestones for this project were achieved.

Mg has poor corrosion resistance; the goal was to demonstrate an advanced, anti-corrosion coating treatment using carbon dioxide (CO_2) chemical plasma techniques. This is important where Mg is joined with steel.

Reviewer 3:
Atmospheric CO_2 plasma is a potential coating process to improve the corrosion resistance of Mg alloys, solving a long standing problem with Mg applications.

Reviewer 4:
The approach appears to be sound. The technique of subjecting a cast Mg part to a CO_2 plasma to create a carbonate, magnesium carbonate ($MgCO_3$), and magnesium oxide (MgO) surface layer appears to be new.

Reviewer 5:
While the primary focus of the work seemed to focus on pure Mg, which has little to no interest for structural applications, the team showed that the application to a structural material, AZ31b, (was not as easy as working with pure Mg. It was difficult to access the relative focus on pure versus structural Mg alloys, but for an exploratory project, the evaluation of the process on the material was excellent.

Reviewer 6:
The approach to performing the work was appropriate to the project objectives. The work follows closely to a 2018 *Nature Communications* journal article by Wang and co-workers which utilized excited CO_2 to modify magnesium oxide (MgO) to magnesium carbonate ($MgCO_3$). This project scaled up the work into sheet form through the utilization of a CO_2 plasma. Two aspects which were not addressed were the broader commercial feasibility of treating large Mg sheets with plasma CO_2, and the use of plasma CO_2 on non-planar geometries.

Reviewer 7:
The project successfully demonstrated the proposed concept. The project included surface modifications and preliminary corrosion testing. Approach of the work was clearly laid out and the tasks were appropriate to accomplish the project goals. The results show improvement in the corrosion performance of the treated parts as compared to the untreated ones.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The performer made excellent progress in this 1-year effort. The project was successfully completed, and all of the milestones were either achieved or exceeded. The demonstrated reduction in corrosion rate was impressive; several orders of magnitude compared to the untreated baseline.

Reviewer 2:
The project was successfully concluded and met all of its technical objectives. The reviewer would like to know if the part needs to be cleaned prior to the plasma treatment, and if the plasma treatment cover all of the surface for parts with a significant surface area.

Reviewer 3:
The project specifically focuses on the primary problems with Mg alloys. While the project had only a small focus on Mg alloys, it clearly evaluated the influence of the $C0_2$-atmospheric plasma ($C0_2$-AP) treatment on pure Mg, which may open opportunities to more effectively apply a similar treatment to structural alloys.

Reviewer 4:
The project demonstrated a significant improvement of corrosion resistance in AZ31 sheet, but did not try the AZ91 magnesium alloy or magnesium AM60 castings.

Reviewer 5:
By using the CO_2 chemical plasma technique, a corrosion resistant coating of MgO and MgCO3 was formed. This treatment significantly reduced the corrosion rate of the CO_2 treated version and untreated Mg and Mg alloys (AZ31B). This treatment also creates a surface layer that has super-hydrophobicity, repelling water and mitigating salt water effects. By using the CO_2 plasma, carbon is well distributed into the dense surface layer of carbonate, $MgCO_3$, and MgO (MgO adsorbs CO_2 to get $MgCO_3$). This was confirmed by both the high annular dark field scanning transmission electron microscopy (HAADF-STEM) with energy-dispersive X-ray (EDX) elemental mapping and X-ray photo electron spectroscopy (XPS).

Reviewer 6:
This was a single year proof of concept project. In that regard, the PIs successfully delivered by demonstrating the formation of a protective layer on the magnesium metal surface by plasma treatment. Further, limited corrosion tests showed the performance improvements. The next barrier for this technology is to optimize the process and develop its performance boundaries.

Reviewer 7:
The project had well focused technical experiments addressing the project objectives in a meaningful and efficient manner.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
As this was a smaller project, little collaboration was required. However, ORNL did show the ability to acquire specimens from team members to facilitate rigorous evaluation.

Reviewer 2:
This was a very nice example of a public-private collaboration, with well-defined roles and coordination. The commercial partner, APS, treated the Mg specimens under different CO_2 plasma operation conditions, while ORNL led the scientific effort and performed testing and evaluation.

Reviewer 3:
The project results indicate good collaboration between the project partners.

Reviewer 4:
Close collaboration with the industrial partner, APS, created meaningful results.

Reviewer 5:
The ORNL project team worked closely with APS, the industry partner, to determine the feasibility of CO_2 plasma treatment on Mg. No other partner was included, however, for this work, and it will be shared with the other project activities under Subtask 5A of the PMCP in Research Thrust Area 5: Exploratory research. The PMCP umbrella is a low-cost approach to coordinating interconnected research.

Reviewer 6:
There was a commercial partner on the project that provided cost share in terms of in-kind work. The partner performed the plasma treatment of the samples.

Reviewer 7:
It was not clear from the presentation what APS Incorporated contributed to the project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
This is a 1-year project with no future work planned. However, there were some suggested future developments on Slide 9. The reviewer would like to have known more about Mg AZ61, Mg AZ91, and rare-earth-bearing Mg alloys. Specifically, the reviewer wanted to know if the plasma treatment will work, and if the CO_2 treatment could be applied to in-line manufacturing of a wrought Mg sheet. One of the corrosion mechanisms is the hydrogen evolution reaction at the transition of metal particles and precipitates that work their way to the surface of the Mg.

Reviewer 2:
The reviewer stated this is not applicable since the project is complete. Next steps will involve investigating additional operational conditions and exploring feasibility as part of a multi-layer coating protection scheme, which seems sensible.

Reviewer 3:
Future efforts could focus on multi-layer coatings or an assessment of changes in physical characteristics caused by the coating. Also, plasma application cost estimates should be performed to determine if this approach is an economically viable approach to develop an anti-corrosion solution for Mg. If this process is deemed cost effective, common automotive Mg alloys should be assessed for anti-corrosion coating formation by using the CO_2 plasma.

Reviewer 4:
The future work needs to address the mainstream Mg applications (AZ91 or AM60 castings with complex geometries).

Reviewer 5:
The project ended in March 2020 and the presenter indicated that the project was 100% complete.

Reviewer 6:
The project was completed.

Reviewer 7:
The project ended.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This is good to see that DOE is providing funding that is somewhat beyond the scope of current OEMs’ focus. The success of this and other work may open doors for OEMs to reevaluate the use of Mg alloys in future vehicles.

Reviewer 2:
This project seeks to address some of the technical barriers associated with increased deployment of lightweight Mg in vehicles. This project is consistent with DOE’s vehicle lightweighting objectives.

Reviewer 3:
Scalable corrosion protection methodologies on lightweight alloys, especially Mg-based alloys, supports DOE’s overall objectives.

Reviewer 4:
Yes, this project supports DOE's overall objectives by providing the knowledge needed to develop high performance materials for lower cost, higher efficiency engines and vehicles.

Reviewer 5:
The project supports DOE's objectives for vehicle lightweighting by overcoming challenges with low density materials such as Mg.

Reviewer 6:
Mg is an important lightweight material.

Reviewer 7:
The reviewer referenced prior comments.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This project was experimental in nature and all of the right tools were applied.

Reviewer 2:
The project appeared to be a well-balanced, well-funded exploratory effort.

Reviewer 3:
Resources were sufficient. ORNL had the laboratory-scale resources required and collaborated with a commercial partner to gain additional expertise and capabilities for the plasma treatment aspect of the project. The project was completed on time.

Reviewer 4:
The entire project and project milestones were completed in a timely fashion with sufficient resources to meet project objectives.

Reviewer 5:
This project was completed on schedule and the funding appeared to be sufficient since all of the stated objectives were completed.

Reviewer 6:
The resources for the project were adequate for achieving the milestones.

Reviewer 7:
This coating is supposed to be low cost.

Presentation Number: mat177
Presentation Title: Novel Aluminum Matrix Composite for Powertrain Applications
Principal Investigator: Zhili Feng (Oak Ridge National Laboratory)

Presenter

Zhili Feng, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

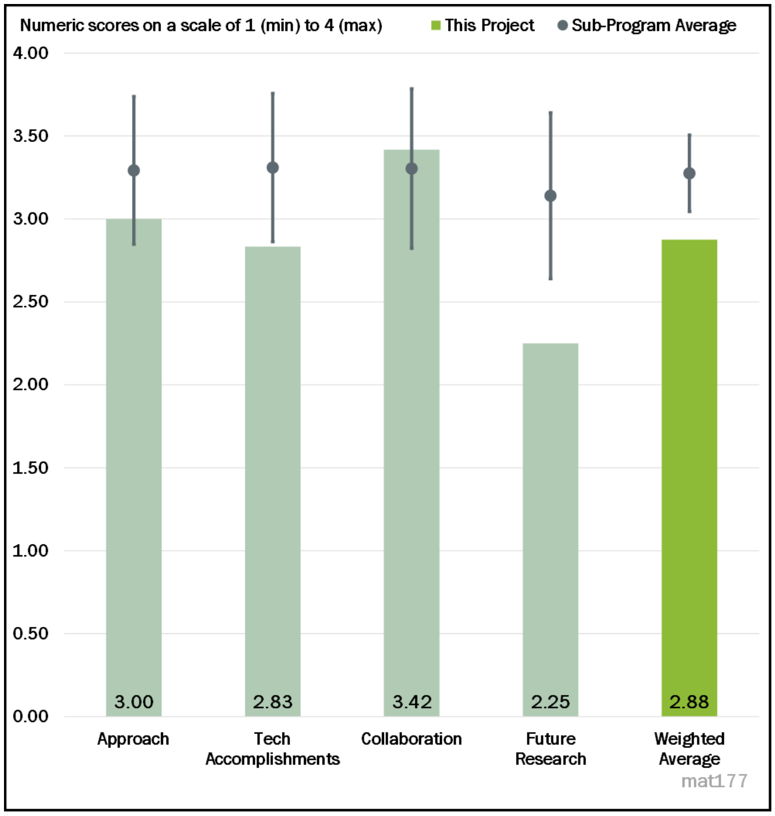

Figure 6-33 - Presentation Number: mat177 Presentation Title: Novel Aluminum Matrix Composite for Powertrain Applications Principal Investigator: Zhili Feng (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

While the overall approach to the fabrication of the specimens is excellent (a definition is provided on the use of solid state processing to overcome limitations of casting), the milestone for the project was a 20% increase in strength at both room temperature (RT) and at 300°C. The project only showed a focus on microhardness at RT, which is assumed to increase when harder materials like carbon and intermetallics are embedded. There is ample literature related to friction stir processing (FSP) that suggests a correlation between microhardness and strength is not linear when embedding products much harder than the base materials. As such, the evaluation of strength by means of microhardness is a significant inadequacy of the presented approach.

Reviewer 2:

Regarding Al matrix composite, the reviewer stated improving strength and greater than 20% weight reduction at RT and 300°C. The technical approach of using FSP does overcome the challenges of producing castings with uniform nanoparticle dispersions. However, the reviewer was not sure if FSP is applicable to the complex geometries of the target applications: turbo compressor housings, cylinder heads, compressor wheels, and pistons. Perhaps FSP is applicable to local strengthening, but the reviewer was not certain if that would be sufficient and cost effective for automotive applications. The reviewer would also like to have known if hardness measurements directly correlate to strength and had a concern over defects that affect strength but that will not show up in microhardness testing. Strength was listed as the primary milestone, but the reviewer did not see any strength testing results.

Reviewer 3:
This exploratory research project aimed to develop new, high strength Al matrix composite (AMC) alloys. The performer's approach was to use solid state processing technologies (FSP and friction stir extrusion [FSE]) to develop the new alloys, and multi component additives such as graphene and carbon, carbide, oxide particles, and intermetallics were incorporated to enhance the material strength. The solid state processing approach seems promising, and ORNL was able to demonstrate the synthesis of a fully consolidated block of an FSP-produced Al composite. This is good; however, the reviewer thought the characterization of the new material could have been somewhat more thorough and responsive to the performance targets. For example, it is still unclear how the mechanical strength of the new material compares to the baseline alloys, since the project team apparently only measured the hardness.

Reviewer 4:
Al-based metal-matrix composite (MMC) materials can potentially be used in cylinder liners, pistons, driveshafts, and connecting rods. Powder metallurgy and mechanical alloying is an expensive process.

Reviewer 5:
This project falls underSubtask 5C of PCMC in Research Thrust Area 5—Exploratory research. The approach used to investigate the impacts of many different materials for powertrain use in the PMCP is excellent. This limits the commitment of government funding with a firm end to the project after 1 year. By completing the project in 1 year, DOE can perform the assessment of potential materials using this cost effective approach. Where applicable, other research programs should consider replicating this approach.

This project ended May 2020, a 1-year assessment. The ORNL budget for this effort was $100,000 (note: PNNL has a parallel effort to investigate different dispersion additives and is also funded at $100,000).

The purpose of this project was to further increase the high temperature strengths of best in class powertrain and body structure Al alloys. Methods under consideration include strengthening of solid solutions; hardening of precipitations and aging (currently used to achieve high strength Al alloys); and dispersion strengthening via mechanical alloying.

The project investigated using the third approach (dispersion strengthening via mechanical alloying) to create Al matrix composites). This approach adds thermally stable, nearly insoluble, and very low diffusivity oxides and other dispersoids to develop the matrix composites. Target applications for this material include a variety of powertrain applications and feedstock materials for additive manufacturing (AM).

The milestone for this project is to develop and validate an Al matrix composite material with an increase in strength greater than 20% at both RT and 300°C, compared to the baseline 7xxx series alloys or cast ACZM alloys. To accomplish this milestone, the researchers used the solid state processes of FSP and FSE to create these composite matrices. Additives considered included graphene and carbon, and nano additives of carbide, oxide particles, and intermetallics.

Reviewer 6:
The approach was to develop MMCs using solid state processing by incorporating second phase reinforcements. The PIs were able to successfully disperse the reinforcements in the metal matrix. However, the overall quality of the MMCs is not clear since the property measurement made was hardness, which is a fairly localized characterization. If some of the bulk mechanical property was reported, it would provide a better picture of the overall material developed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
As referenced in prior comments, the objective was to develop Al alloys with increased high temperature (HT) behavior. However, the results reported are only for ambient conditions hardness. It would have been really nice to see the strength data at ambient conditions and at elevated temperatures. The outcome of the project is successful dispersion of the reinforcements in the metal using solid state processing with demonstrated hardness enhancements.

Reviewer 2:
Considering the short, 1-year timeline, the performer made acceptable progress. However, the key project milestone was a mechanical strength increase, whereas the performer measured hardness. It would have been helpful to see results from conventional strength tests. The assessment method chosen (indentation microhardness) is a localized test method that probes only a few millimeters, maximum, into the surface. It may not give an accurate sense of the general or bulk properties of the material, which will be key in the structural applications targeted. The reviewer also does not see any evidence of measurements at elevated temperatures (which had been another project milestone).

Reviewer 3:
The project only reported microhardness data. No other properties were tested.

Reviewer 4:
The project set out to demonstrate a strength increase at both RT and at 300°C. At 85% complete, the project team has shown none of the following: evaluation of material at temperature; evaluation of properties beyond microhardness; or plan to do anything beyond evaluate heat treatment. The reviewer, therefore, cannot find a plan or progress toward the goals specified in the work and milestones shown for this project. The team did make significant work at fully densifying the FSP product, which is a commendable start.

Reviewer 5:
The reviewer did not see any strength testing or any testing at 300°C. Both of these were primary objectives, so it does not appear that accomplishments met the project goals. The project was to be completed May 2020. The presentation says it is 85% complete, but no explanation on schedule changes was given.

Reviewer 6:
The researchers created Al composite matrices for mechanical property testing using AA6061 and AA7075 as the baseline material, and then integrated the additives using the solid state friction processes. The matrix materials included the additives carbon and intermetallics, and silicon carbide (SiC) at 3%-10% weight.

The matrix composites developed included 6061 matrices with two different additives. Up to a 25% increase in microhardness was achieved by adding intermetallics and SiC particles, and the solid state processing resulted in a uniform distribution of intermetallic particles.

The matrix composites developed using 7075 baseline as the material added carbon and intermetallics. Up to a 50% increase in microhardness with a 5% weight intermetallic additive was achieved. A 15% increase in microhardness with a 3% carbon weight was also achieved.

Heat treatment was applied to both matrices to the temper 6 (T6) level achieved a 20%-30% improvement.

The reviewer noted that the PI did not answer the questions. Several outcomes from this research are unclear, although he did indicate that the project successfully demonstrated the feasibility of solid state material processing with mechanical alloying to synthesize stronger and lighter Al metal composite materials for engine and body structures. The reviewer believes that this project did accomplish this goal, and that mechanical alloying through solid state processing should be considered when developing new material matrices.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There was excellent coordination with the PNNL processing team.

Reviewer 2:
The collaboration with PNNL seems appropriate, as each laboratory has unique processing capabilities. Coordination between laboratories was good. Being that unique alloys were shared, however, all evaluation presented herein seems to be in AA6061 and AA7075.

Reviewer 3:
The project was conducted at ORNL and regular collaboration discussions occurred with PNNL.

Reviewer 4:
This was mainly a parallel effort between the two laboratories. Collaboration included frequent conference calls and web meetings, but it looks like work was largely done separately. There was some material sharing.

Reviewer 5:
Several related projects are being performed in parallel since this is part of the PMCP. For this activity, a parallel research activity is occurring at PNNL, which is focused on ShAPE processing. Laboratories have frequent conference calls and web meetings to coordinate on materials and additives (e.g., ORNL provided the ACMZ alloy to PNNL).

Reviewer 6:
The project shows good collaboration among several partners.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The proposed future work (the remaining work for this effort) seems to miss the mark in achieving the milestone documented in this presentation. Mechanical properties do not linearly correspond to microhardness for FSP samples with additives much harder than the base material. While students at universities may use this tactic because of a limitation on batch size of material to test, the objective of this study was to produce a sufficient quantity of materials to evaluate properties—rather than microhardness alone—and no plan is presented to actually do that with the funding provided.

Reviewer 2:
The project appears to have ended. Proposed future research is on post process heat treatment and completing microstructure, mechanical property, and functional property characterization. It was unclear if all of that was going to be done under this project or a future project.

Reviewer 3:
The project has ended.

Reviewer 4:
The reviewer hopes to see more properties tested as planned in the future work.

Reviewer 5:
The project ended, and it was a 1-year year project.

Reviewer 6:
The reviewer believes the project has ended, but the PI did not confirm. Several companies have expressed interest in this activity and taking the results forward. Specifically, General Motors (GM), Powertrain, Magna and Cosma, and Ford have all expressed interest. For future research, the PI proposed completing a heat treatment study of the matrices for the T6 and T651 conditions. Other proposed future work included assessing the microstructure as well as the mechanical and functional properties of these matrices.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project has excellent alignment with DOE's goals of achieving decreased carbon emissions and improving fuel economy with better engineered material performance. The reviewer applauds the foresight to reach beyond traditional processing methodologies to enable lighter and stronger powertrain materials.

Reviewer 2:
Improved materials are essential for new technology to improve fuel efficiency or extend the range of EVs.

Reviewer 3:
This project, focused on the development of higher strength structural Al alloys, is consistent with DOE's vehicle lightweighting objectives.

Reviewer 4:
Yes, this project supports DOE's overall objectives by providing the knowledge needed to develop high performance materials for lower costs and higher efficiency engines and vehicles.

Reviewer 5:
DOE's objective is reducing fuel consumption and vehicle weight. In this regard, the project addresses the need to develop high strength, lightweight alloys that can operate at higher temperatures.

Reviewer 6:
Al-based MMCs could play an important role in some engine applications. The key is to reduce the cost. The material and process combinations in the current project seem expensive.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources appear to have been sufficient.

Reviewer 2:
This project was completed on schedule and the funding appeared to be sufficient since all of the stated objectives were completed.

Reviewer 3:
Resources at both ORNL and PNNL were available and sufficient for the project.

Reviewer 4:
The project seems to be behind, perhaps due to COVID-19.

Reviewer 5:
The resources provided were sufficient for the tasks at hand; however, the team seems to have been distracted from the actual goals of the work.

Reviewer 6:
It does appear that all of the milestones have been achieved to date. The reviewer commented that 85% of the budget to produce samples and conduct harness testing appears to be excessive.

Presentation Number: mat179
Presentation Title: Development of High-Temperature Sample Environment for Advanced Alloy Characterization Utilizing High-Speed, Micron-Resolution X-Ray Imaging Techniques
Principal Investigator: Dileep Singh (Argonne National Laboratory)

Presenter

Chih-pin "Andrew" Chuang, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

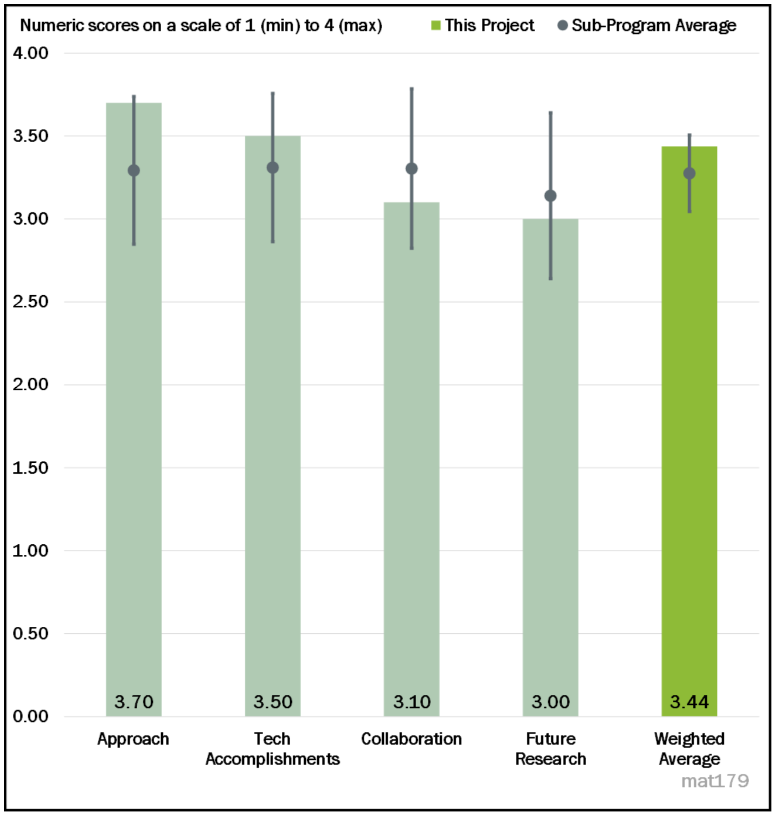

Figure 6-34 - Presentation Number: mat179 Presentation Title: Development of High-Temperature Sample Environment for Advanced Alloy Characterization Utilizing High-Speed, Micron-Resolution X-Ray Imaging Techniques Principal Investigator: Dileep Singh

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This is a well done, nice piece of work, and it is great to add this capability. The use of induction heating to decrease local thermal loading was a great idea. The rapid heating and cooling are important to prevent grain growth and look at transformation mechanics.

Reviewer 2:

The approach for the project appears well thought out and logical for this relatively specifically targeted project. The team appears to have studied current testing environments in detail and designed this project to overcome the shortcomings of existing approaches. In particular, the focus on induction heating not only targets key shortcomings, but also takes advantage of a rapidly improving technology. In addition, the use of a susceptor to achieve temperature uniformity appears to have been a key decision.

Reviewer 3:

With a focus on designing, building, and testing a sample environment that can be utilized with the synchrotron, the team seemed to stay focused on providing an environment and control that could be used in the spatial and environmental constraints of the facility.

Reviewer 4:

The method is robust, and the equipment has been well designed to provide the needed information.

Reviewer 5:
The work is very useful and potentially has a very high impact.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
This is a well scoped project that clearly met all of the initial intentions of the work.

Reviewer 2:
The project appears to have achieved its technical milestones of developing a system capable of reaching stable, higher temperatures, and completing experiments at temperatures significantly above currently available levels. Therefore, a proof of concept has been completed. The team is still waiting on another material sample that should offer an opportunity for conducting even higher temperature experiments.

Reviewer 3:
The teams seem to have been able to accomplish all of the directives that were setup to accomplish.

Reviewer 4:
The reviewer would like to see a more quantitative assessment of the capability for various types of materials and suggests showing at what accuracy the team reached the desired temperature and the error in the temperature measurement.

Reviewer 5:
Slide 4 talks about very high resolutions, but the reviewer cannot tell if these resolutions were accomplished by looking at Slide 7. Slide 8 discusses two user experiments that were conducted. The reviewer suggests that the project team provide this imaging and temperature data because it is difficult to appropriately rank the progress without this information. In addition, the reviewer would like to know if the temperature data in Slide 6 is from these experiments or a generic experiment. The reviewer is not concerned that ambitious values of imaging or temperature profiles were not obtained, but rather what was indeed obtained.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer does not think this was an issue, given that all of the project scientists were in the Applied Materials Division at ANL.

Reviewer 2:
While the project itself was designed to be completed by a team solely from ANL, the team did work with two user groups- one from MINES Saint-Étienne, France, and the other from the California Institute of Technology. These organizations had testing needs which matched the new system's capabilities, and thus assisted in validating the operation by participating in testing.

Reviewer 3:
While collaboration exists, there was little that was presented showing the benefits of the collaboration to the current work.

Reviewer 4:
It appears that the collaborators have provided the problems and that the experiments are in progress. Conversely, it is that the "Status" is related to work done with the collaborators? For example, does the comment "Conducted two user experiments" mean that the experiments were related to the two collaborators? Some details would be helpful.

Reviewer 5:
Collaboration seems good.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
Adding a load frame to the system to characterize the material under load at an elevated temperature is a good future enhancement. Quenching would also be a great feature.

Reviewer 2:
The project is effectively over, with only a few remaining activities to be completed that had been delayed. The team has identified activities for future research to further improve the system.

Reviewer 3:
The reviewer is not clear how the proposed future research connects with the problems of the two collaborators. The engineering purpose of the work is not clear. What will this unit provide in terms of understanding certain mechanisms? What is the contrast mechanism for recovery and recrystallization in a tomography unit?

What mechanisms will heating and cooling tell the project team at a 0.5 um resolution? Have the authors considered using this equipment for sintering studies or for looking at damage during high temperature deformation?

While the technique is extremely ambitious and challenging, the use of the equipment regardless of where we land on its capability should be detailed better.

Reviewer 4:
The reviewer indicated no comments.

Reviewer 5:
The reviewer indicated no comments.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project supports the goal of using synchrotron X-ray techniques for material characterization to facilitate powertrain materials research as the market demands lower carbon emissions and higher power density.

Reviewer 2:
The purpose of the project is to increase the temperature testing capability for materials in order to accurately characterize the properties and performance of advanced materials that can contribute to increased efficiency.

Reviewer 3:
This work is highly relevant to DOE objectives and will hopefully enable future characterization that is beyond the current capabilities. An excellent direction and goals for the overall scope have been defined.

Reviewer 4:
If the time of HT materials processing can be shortened, then it will greatly add to energy reduction and missions.

Reviewer 5:
This project is very supportive, as it can enable HT, in situ experiments.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This is a well-done project on a small budget. Nice work.

Reviewer 2:
The project appears to be staffed by very capable people.

Reviewer 3:
Resources appear sufficient and the project is nearly complete.

Reviewer 4:
While the setup and control could have been done for much less, the integration with an X-ray source sufficiently complicates the work to justify the resources.

Reviewer 5:
Resources are good.

Presentation Number: mat180
Presentation Title: Reducing The Weight of Vehicle Components via Lost-Foam Casting of Ductile and Austempered Ductile Iron
Principal Investigator: Sarah Jordan (Skuld)

Presenter

Sarah Jordan, Skuld

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

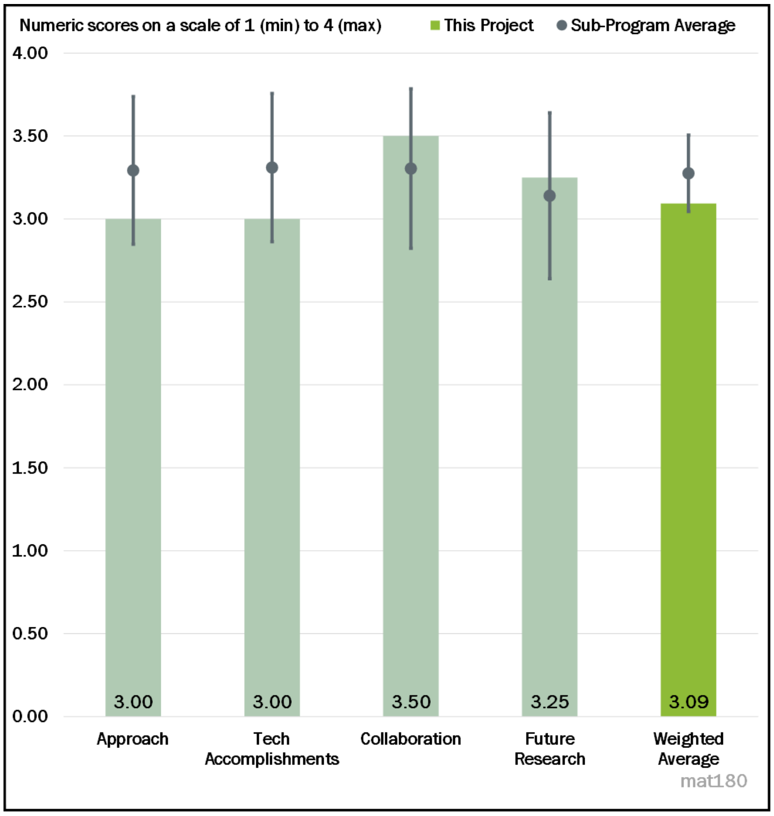

Figure 6-35 - Presentation Number: mat180 Presentation Title: Reducing The Weight of Vehicle Components via Lost-Foam Casting of Ductile and Austempered Ductile Iron Principal Investigator: Sarah Jordan (Skuld)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach to developing thin wall ductile Fe components using lost foam casting appears to be feasible. The project is straight forward and well designed, but the lack of a larger scale furnace for casting heats appeared to hinder progress, and thus the project has not been able to demonstrate full industrial viability. Since the company has a long history in making thin wall ductile Fe, it is no surprise that this project has seen reasonable success.

Reviewer 2:

It seems that this project is partially complete at this point, but the reviewer is not sure if the project will meet the stated deliverables by the end of June 2020. Technical barriers have been partially addressed. For example, the reviewer would like to know if it has been demonstrated that the lost foam casting process will lead to 1-mm thick ductile Fe castings that are largely defect free.

Reviewer 3:

The approach for the project was well laid out. Key technical barriers and metrics for the success were well defined. Specific characterizations that were needed were also outlined.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The project made significant progress toward demonstrating the feasibility of thin walled ductile Fe castings. Various tests were conducted, including microstructure, surface roughness, nodule count, fluidity, etc., to show that the casting can be fabricated. However, it would have been nice to see some mechanical property data. The project did demonstrate elimination of massive carbides for thin wall castings, which is an excellent progress.

Reviewer 2:
This project has some lofty and certainly laudable technical plans. Progress has been good, but it seems that the project is only partially completed. The project has demonstrated reduced and eliminated massive carbide defects in castings as thin as 1.8 mm, but the reviewer would like to have known if defect free lost foam castings at a nominal thickness of 1 mm were produced. In addition, it is unclear if the proposed lost foam casting process is a high volume production process or if it is limited to the small-scale production of parts.

Reviewer 3:
Two of the three identified objectives have successfully been demonstrated. A laboratory-scale demonstration of thin wall cast ductile Fe with dimensional control within 5% illustrates satisfactory progress.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaborations with the main subcontractors appear to be strong; however, collaborations with automotive manufacturers would strengthen the work.

Reviewer 2:
The project was very well coordinated with The Ohio State University, Worcester Polytechnic Institute (WPI), etc.

Reviewer 3:
Collaboration with Ohio State and WPI has provided non-redundant and critical contributions to the project regarding laboratory-scale casting production and surface roughness measurements. The surface metrology approach seems standard. Surface roughness (Ra) is not a good indicator of surface functionality, and the reviewer would like to know what functional aspects of the surface need to be controlled (e.g., appearance, lubricant transport, etc.). It seems to be purely appearance controlled (i.e., no Styrofoam cup topography?).

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
Although this was a 1-year, Phase 1 project, the PIs have laid out a well-defined plan for Phase 2.

Reviewer 2:
A brief outline of the predictive model would help. Also, process control ranges need to be established. It seems like this will require more than just Calphad modeling, (e.g., it will need to couple heat transfer, fluid flow, microstructure evolution during solidification, and defect nucleation). It seems that this might be way beyond the scope of this project, and the reviewer would like answers to the following questions:

- Will this part of the project be developed at Ohio State?
- Is lost foam more costly than other part casting processes?

- How much cost will the coating add to the lost foam process?
- Will the cost for mass produced (e.g. millions per year) parts outweigh the potential benefits?
- Does the X-ray radiography have a high enough resolution to detect the range of porosity that would impact pat performance?

Reviewer 3:
The future research outlined is appropriate given the results obtained in Phase I of the research. The predictive modeling efforts and large-scale production are the strongest endeavors. However, the modeling efforts will depend on a strong dataset for input parameters. It is unclear where the fundamental data that will be integrated will come from, and if it will ultimately validate the models.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Weight (mass) reduction of cast parts is critical for automotive applications.

Reviewer 2:
Yes, thin wall sections of high strength metals in automotive components significantly contributes to DOE's lightweighting initiatives.

Reviewer 3:
Thin walled ductile Fe castings without massive brittle carbides will allow the use of Fe-based castings for various vehicle components. Clearly, using thin walled, high strength materials will lead to vehicle weight reductions, and consequently, significant fuel savings.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Yes, the resources were commensurate to the project tasks.

Reviewer 2:
Resources are sufficient for now, but it is unclear if adequate resources are available to finish the project, especially the development of the predictive model from casting to part performance in a vehicle assembly.

Reviewer 3:
Resources appear to be sufficient given the stated objectives. The only resource that was lacking was a production-scale furnace. However, this will be addressed in future research.

Presentation Number: mat182
Presentation Title: High-Strength Aluminum-Graphene Composite for Powertrain System
Principal Investigator: Xiao Li (Pacific Northwest National Laboratory)

Presenter

Xiao Li, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

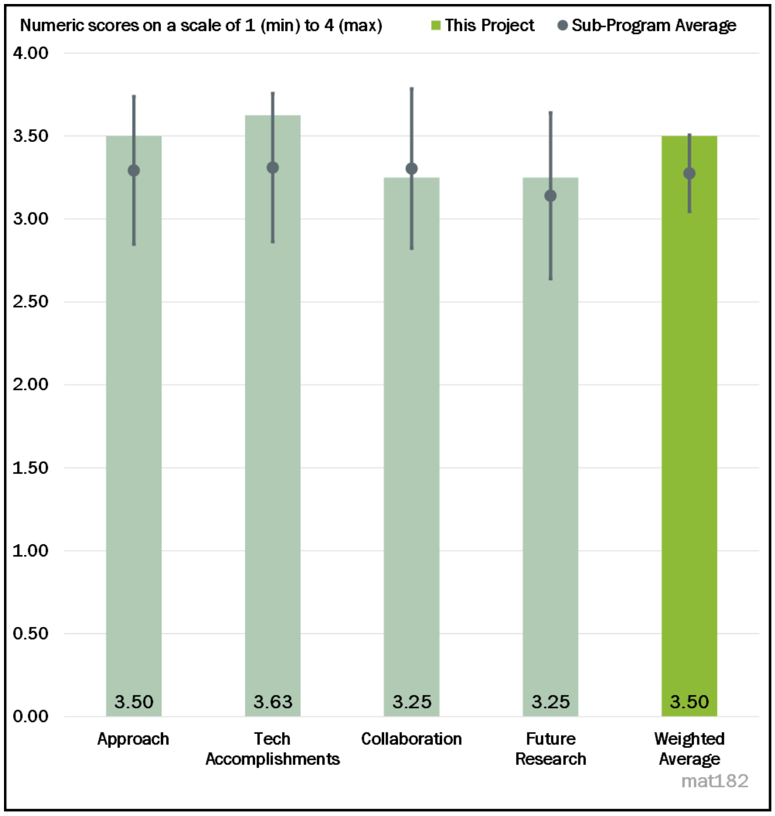

Figure 6-36 - Presentation Number: mat182 - Presentation Title: High-Strength Aluminum-Graphene Composite for Powertrain System Principal Investigator: Xiao Li (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The performer used the ShAPE process to produce an Al-graphene composite. This material system is promising due to its outstanding toughness and fatigue strength; however, two main technical barriers are segregation (caused by the combination of density differences between the metal and graphene, and poor mixing) and overheating (formation of weak intermetallics and low quality composite caused by excessive processing temperatures). The project team did a nice job clearly explaining the barriers and how the ShAPE technique could address them through enhanced mixing and low temperature processing. There are still some potential concerns about scalability for this manufacturing technique that will need to be addressed in the future; however, for an early stage exploratory effort, this appears to have been a well planned and executed study.

Reviewer 2:

The project involved using solid state mixing of particulates and reinforcements in Al alloys to enhance the mechanical properties. The project uses ShAPE technology that allows mixing of the reinforcements in the alloy and extrusion of the composite in wire form. The project was well designed, with key steps clearly outlined. The approach adequately addressed the technical barriers.

Reviewer 3:

There is a well-developed approach using the pre-existing ShAPE process at PNNL.

Reviewer 4:
The use of ShAPE is a novel way of incorporating graphene into Al to form a composite.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
There were two milestones in this 1-year effort, and both were met or exceeded (the project has now ended). The first was to produce a void-free aluminum graphene composite (AGC) with uniform dispersion. The second was to improve mechanical properties by 15% at room temperature and at 300°C. The first milestone was met. The second milestone was substantially exceeded, with a demonstrated increase of 40%-100% in strength. This was a very successful project.

Reviewer 2:
The project accomplished two key objectives: (a) a void free composite with reinforcements dispersed and (b) a greater than 15% improvement in mechanical properties at room temperature and at 300°C. The progress made in the project has been outstanding for a 1-year exploratory project. There are additional targets that the PIs have proposed for future work.

Reviewer 3:
The composite material properties were considerably improved and exceeded the targets.

Reviewer 4:
The team achieved alloy development with well mixed aluminum and graphene and a backwards extrusion pressure under high temperatures and pressures (using ShAPE). The alloy has a uniform nanostructure and a processing temperature below 450°C. Brittle intermetallics and melting segregation are avoided. The reviewer would like to know if the proposed Al and graphene material is limited to Al7075.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There was outstanding collaboration with staff at PNNL and ORNL in terms of producing the alloy and characterization.

Reviewer 2:
This was mainly a parallel effort between the two laboratories. Collaboration included conference calls and web meetings, but it looks like work was largely done separately. There was some material sharing.

Reviewer 3:
It seems that ORNL provided some cast materials, but the reviewer would like to know what else ORNL contributed to the project.

Reviewer 4:
The reviewer could not tell which part of the work was conducted at ORNL. The ShAPE equipment is at PNNL, so the reviewer expects that ORNL conducted some of the characterization.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The reviewer agreed that the next step is to scale up to a larger diameter stock. The 0.1 inch diameter wire is good for a proof of concept but would need to be much larger to make production parts.

Reviewer 2:
The project has ended.

Reviewer 3:
The project has ended and the PI notes that there may still be an opportunity for improvement, as the theoretical yield strength of the AGC has not yet been achieved. In addition, the extrusion speed needs to be increased to meet industrial demands. The wire diameter will also need to be increased to create full size components.

Reviewer 4:
This process is interesting but likely will be very costly once scaled up to make commercial parts for the automotive industry, for example. Adding heat adds cost, meaning there is a costly Al alloy (7075), with a costly additive (graphene), combined with a costly manufacturing process (ShAPE). The reviewer wants to know if the project team has explored high speed rotational casting, if the team has focused on less costly Al 6xxx alloys, and if the addition of graphene will mitigate 7075 corrosion. It seems that scaling up the current wire extrusion process will require substantial manufacturing complexity and cost. In addition, the reviewer wonders if the mechanical property benefits of as-produced Al-graphene alloys outweigh the manufacturing and material costs, and if it can compete with processes such as 3-D printing for powertrain components which are currently the subject of enormous attention. Lastly, the reviewer questioned if the team can partner with a company that is directly involved in making powertrain components for the automotive industry. It seems that this could give the project much direction and focus.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project is related to the development of lightweight Al alloys with improved mechanical performance at elevated temperatures. Successful demonstration can lead to use of the alloys for engine components to allow operation at high temperature for higher fuel efficiency and reduced vehicle weight.

Reviewer 2:
This project supports the DOE lightweighting objectives for transportation.

Reviewer 3:
This project, focused on development of higher-strength structural Al alloys, is consistent with DOE’s vehicle lightweighting objectives.

Reviewer 4:
This project does support the DOE objective of improved fuel economy by lightweighting.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources appear to have been sufficient.

Reviewer 2:
This was a 1-year project and the teams in place were able to reach the objective.

Reviewer 3:
Resources at both PNNL and ORNL were sufficient and available. The ShAPE processing equipment was available to the project.

Reviewer 4:
Resources seem sufficient, but the reviewer would like to know if ORNL contribute more in the future.

Presentation Number: mat183
Presentation Title: High-Temperature Coatings for Valve Alloys
Principal Investigator: Sebastien Dryepondt (Oak Ridge National Laboratory)

Presenter

Sebastien Dryepondt, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

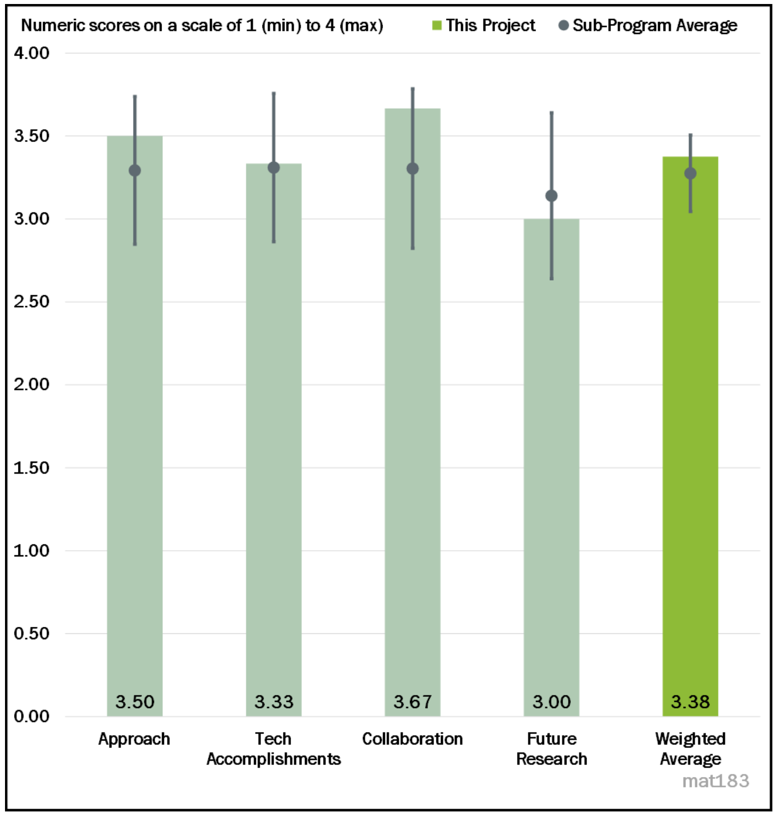

Figure 6-37 - Presentation Number: mat183 Presentation Title: High-Temperature Coatings for Valve Alloys Principal Investigator: Sebastien Dryepondt (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

There is a great use of modeling and experimental work in the plan.

Reviewer 2:

This reviewer referenced Subtask 2A3—High-Temperature Coatings for Valve Alloys within the PMCP of Research Thrust Area 2—Cost Effective Higher Temperature Engine Alloys, Some additional funding is provided under Subtask 4B – Advanced Computation of Research Thrust Area 4B—Advanced Computation under the PMCP. The approach used to investigate the impacts of many different materials for powertrain use in the PMCP is an excellent approach to use.

The reviewer reported that the fiscal year (FY) 2020 budget was $197,500 (subtask 2A3 funding was $175,000 and subtask 4B funding was $22,500). Additionally, this is a 5-year (2018-2023) activity, and the period of performance is 30% complete. The project aligns with the PMCP timeline.

The goal of the project is to enable lower cost, higher strength alloys for valve operations. The team is trying to develop an alternate to alloy 751 (the industry standard for yield strength), which operated at an increased operation temperature for higher efficient engines that require improved material performance and increased oxidation resistance. It is expected that advanced combustion engines (ACE) will require valve materials to withstand 50,000 pounds per square inch (psi) at an operating temperature of 870°C. Therefore, there is a need to develop materials to withstand this environment. The approach used within this project to achieve those results is an oxidation resistant coating applied to lower cost, higher strength alloy materials.

Reviewer 3:

The reviewer asked what oxidation mechanism is being mitigated. If it is oxidation plus fatigue, then please describe why a particular type of coating is needed and why the specific coating was selected. The reviewer asked for a description of the need for a 50-µm thick coating in terms of fatigue and the fact that a diffusion layer is needed for some reason. If this may be proprietary, a few words on how the coatings were deposited would be helpful.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Alloys with significantly increased strength at high temperatures have been achieved. The team did great modeling work to identify coatings to enhance oxidation resistance. To date, high-cycle fatigue (HCF) results are encouraging and there are no coating failures.

Reviewer 2:

A slurry coating and thermal spray coating (MCrAIY) was applied to the 2687 alloy. There was a variation in successful coating depositions. The thermal spray coatings had homogeneity issues in the first batch. As such, the deposition parameters and heat treatment need to be optimized for this approach to be successful. Titanium (Ti) content of the alloy created oxygen (O_2) sensitivity during annealing.

Leveraging the advanced computing capability (included as part of the funding for this project), the project team successfully predicted the microstructure using coupled thermodynamic and kinetic models. These calculated phases are consistent with the phase mapping for slurry coatings. The project team demonstrated significant oxidation resistance using the nonoptimized slurry coating at 900°C. Although the alloy contains Ti for strength, it does create two issues: reduced oxidation resistance and diffusion from the substrate to the coating surface. A concern here is the cost to implement a homogeneity deposition approach for coating the alloy.

Initial HCF tests of coated specimens show no cracks in the coating. Cycles to failure of coated specimens was similar to that of the standard alloy.

The reviewer understands that this project is to develop HT coatings for valve alloys; however, the cost for slurry and spray coatings was never addressed, although it was stated as a clear barrier to HT coatings.

The milestones scheduled for this period include initiating HCF testing of the high strength, coated valve alloy (complete) and writing a paper on the HCF properties of the coated valve alloys (on target).

Reviewer 3:

Slide 8 talks about the bare 31V alloy. Can this material be defined? Is the team trying to match 31V with the 2687 plus a coating?

Referring to Slide 8, if the presence of Ti is an issue, how will this be circumvented?

On Slide 9, there are three data points. The reviewer assumed that two of them in blue are 31V, although this is not stated explicitly. Is it that the base material will control fatigue because the third bullet states that there are no cracks in the coating? Are there any fatigue data for the 2687 alloy without a coating as a baseline?

It would have been helpful to state that a certain mechanism or outcome in the coating layer would be of value (i.e., thickness, interdiffusion layer, etc.), and that this was accomplished. Slide 7 talks about the elemental distribution calculated against what was measured. While these agree, is this the profile that the team wants? Does the team prefer a thicker interdiffusion zone (IDZ) or a thinner IDZ? Is the presence of the sigma phase a benefit or a detriment?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
A collaboration between the lead National Laboratory (ORNL), academia (Stony Brook University) and an industry partner (Flame Spray, Inc.) was established. Also, the team leveraged advanced computing capabilities as well as coordinated within the PMCP to ensure communication between research institutions.

Reviewer 2:
There is an excellent selection of collaborators. It would be nice to have an OEM, even if in a support or consulting role. It will be interesting to exploit the synchrotron setup in MAT179 to look at the cycling effects on interfacial behavior.

Reviewer 3:
There are two industry partners.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
Only a very high level plan was presented, making it difficult to assess all aspects of this question. The reviewer would have liked to see at least one slide which provided an overview of the 5-year plan with specific milestones and decision points.

Reviewer 2:
The PI for this project has proposed several areas for future research, with the most important being the optimization of the coating application to ensure homogeneity in the coating deposition. If this cannot be achieved cost effectively, then this process will not be a viable approach to coat valve alloys.

The PI also proposed continuing the cyclic oxidation and HCF testing at higher temperatures. Also, the use of the advanced computational facilities to predict lifetime through couple thermodynamic and kinetic modeling is an effective approach to ensure that these solutions are viable prior to bench scale testing.

If there are cost benefits to using these methods of coating the alloy, this should be included as part of the project. Also, future work proposed by the PI suggested the evaluation of strategies to mitigate the deleterious effect of Ti. The reviewer suggests that the application of these HT coatings to lower costs and lower TI content alloys is developed in parallel to this coating assessment as part of this work. This might be a better approach to addressing the concerns that Ti is presenting.

Reviewer 3:
The plans for future research are well laid out and map the results section. However, there is no mention of what optimized coating fabrication will be used for, and what strategies will be used to mitigate the deleterious effect of Ti, considering Ti is needed for some other reason. The reviewer would like to know if this can be eliminated if Ti is not needed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Enabling increased operating temperatures in combustion engines will enable improved fuel efficiency.

Reviewer 2:
Yes, this project supports the overall DOE objectives by providing the knowledge needed to develop high performance materials for lower cost, higher efficiency engines and vehicles.

Reviewer 3:
This technology can enable more efficient powertrains in terms of improved fuel economy and reduced emissions.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project appears to be achieving the stated milestones within the allocated budget.

Reviewer 2:
This project was completed on schedule and the funding appeared to be sufficient since all of the stated objectives were completed.

Reviewer 3:
A good selection of researchers are on this project.

Presentation Number: mat184
Presentation Title: Development of Cast, Higher Temperature Austenitic Alloys
Principal Investigator: Yuki Yamamoto, Michael P. Brady (Oak Ridge National Laboratory)

Presenter

Yuki Yamamoto, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

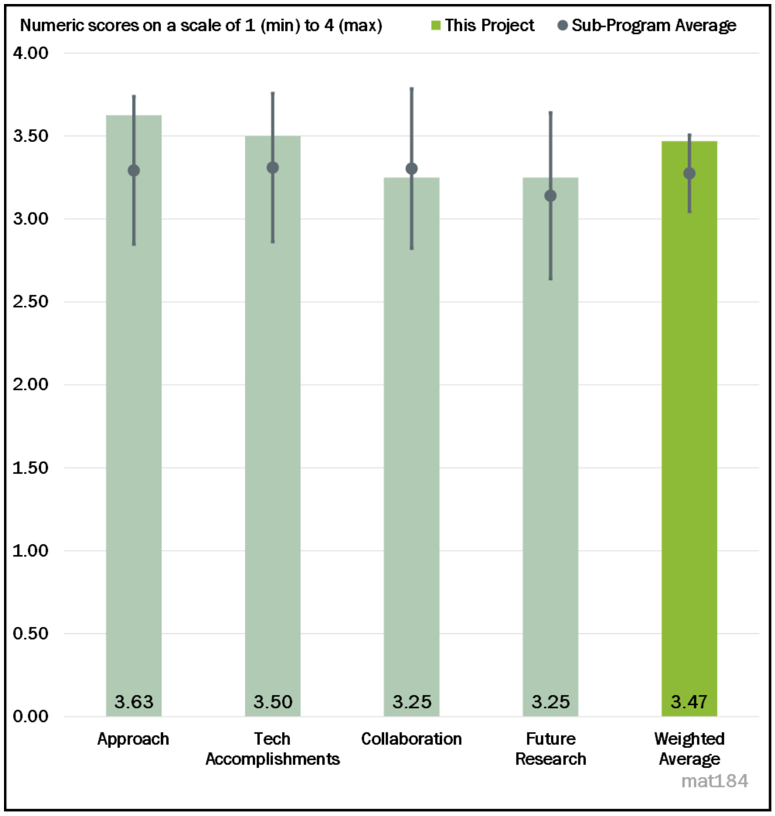

Figure 6-38 - Presentation Number: mat184 Presentation Title: Development of Cast, Higher Temperature Austenitic Alloys Principal Investigator: Yuki Yamamoto, Michael P. Brady (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The objective of this project is to develop cost effective, Fe-based (austenitic) alloys that can be used at temperatures of 900°C-950°C, while providing good oxidation resistance, high strength, and creep resistance. The approach used here is to develop alumina-forming austenitic (AFA) alloys. The performer is taking advantage of integrated computational materials engineering (ICME) approaches, and the project includes validation of newly developed materials at multiple production scales, including collaboration with a commercial partner to produce industry-scale castings. The approach seems sound.

Reviewer 2:

This reviewer referenced Research Thrust Area 2B1—Cost Effective Higher Temperature Engine under the Powertrain Materials Core Program, and commented that the approach used to investigate the impacts of many different materials for powertrain use in the PMCP is an excellent strategic tactic to leverage limited resources and investigate several potential solutions.

The FY 2019 budget was $275,000 and the FY 2020 budget was $275,000. The period of performance for the 3-year (2018-2021) activity is 50% complete and the project aligns with the PMCP timeline.

There are several barriers to overcome and technical targets to hit. Internal combustion engines currently need higher temperature capable materials to permit high efficiency operation; however, the current cost of these materials is high. Traditional development of new materials is costly and time consuming, and it is often difficult to scale new materials to commercial level. Current alloys lose oxidation resistance and strength above 800°C, and Ni-based alloys cost 3-10 times more than Fe-based materials.

So, for this project, the objective was to develop Fe-based alloys for 900°C-950°C applications. By using the aluminum oxide (Al_2O_3) scale formation (AFA alloys), improved oxidation resistance can be achieved. The integration of nanoprecipitation can increase strength and creep resistance. All of these will be demonstrated using an Fe-based alloy with Ni percent weight at or below 25%.

All milestones have either been completed on schedule or early. Upcoming milestones are on target for completion (however, the COVID-19 impact may delay this project slightly because of restricted access to the laboratory).

The approach to accomplish this project is a well thought out stepwise process. The project approach contains four major steps as follows: cast Al-forming austenitic alloys that will provide better protection than the chromia scale; using ICME (CALculation of PHAse Diagrams [CALPHAD] databases) to minimize the alloy selection iteration process; validating material physical properties in the laboratory via experimentation with 1 pound or less of material; and evaluating production feasibility with trial industry scale-up heats using 50 pounds or more of material.

Reviewer 3:
There is a well-rounded approach focused on surmounting the stated technical barriers.

Reviewer 4:
The project approach is well planned. The barriers for developing Fe-based alloys to operate at greater than 900°C have been identified. The approach to address the barriers has been laid out well. However, a task to conduct a techno-economic analysis for the final selected composition is missing, and the reviewer would like to have known if there is a target cost value. If so, it would be helpful to know if some preliminary analyses suggest that it could be met.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
This project has made excellent progress. Using modeling, various alloy compositions were identified. The laboratory-scale fabricated alloys were tested for creep and oxidation behaviors. Several compositions showed the target performance. Based on these results, large-scale heats have been conducted and material properties are being characterized. The progress has met the project milestones.

Reviewer 2:
A new alloy design was developed to maximize strengthening carbide ($M_{23}C_6$) formation. To achieve this, five AFA alloys were tested (22-25% Ni) to determine maximum $M_{23}C_6$ formations for strengthening. Although all five are oxide inherent, Al_2O_3 is far more resistant in water (H_2O) exhaust than Cr (III) oxide (Cr_2O_3) resists rapid Feoxide formation and spallation.

This new alloy improved creep performance, exceeding competitive industrial cast austenitic steels. All of this was done with AFA5, with a raw material cost within 5% of the HK30Nb alloy. It was noted that Ni variation has little impact on creep but having less than 20% Ni led to a negative impact on oxidation.

Trial-scale industrial heats of AFA5 (80 pounds of material) is underway, with property screening in progress to determine the tolerance of the alloy to typical microstructure and chemistry variations in the industrial casting process, which will be key.

Reviewer 3:
Five alloys showed excellent oxidation resistance in simulated exhaust gas environments through Al_2O_3 scale formation. Protective Al_2O_3 on AFA5 after a 1,000-hour test improved creep performance in cast austenitic steels.

Reviewer 4:
The project is generally on track and meeting the milestones, with a possible delay in one upcoming go/no-go decision milestone due to a slowdown in experimental work during COVID-19. The down-selected alloy is on track to meet creep and oxidation targets; however the team reports that it may have degraded strength, and this is being investigated.

The milestones appear to be focused primarily on the research process, rather than the performance of the materials developed. For example, one milestone is to “procure an industrial cast heat of down-selected AFA,” and another is to “complete at least 500 one-hour cycles of oxidation testing.” There is not much apparent focus on the technical metrics against which new materials are being measured (strength targets, etc.). This would be useful context for understanding and assessing the technical progress being made and to maintain project momentum.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Partnerships with other National Laboratories and industry are in place. MetalTek International is an industry materials supplier under subcontract to supply the alloys. PNNL is collaborating with ORNL in other PMCP thrust areas. Specifically, collaboration within the PMCP Thrust Areas 4A and 4B were to leverage advanced characterization and computational models. PNNL will help with microstructure characterization (scanning electron microscope [SEM], transmission electron microscopy [TEM], atom probe tomography [APT]) under PMCP Thrust Area 4A, to aid in understanding and optimization during alloy design and scale-up efforts. ORNL Computational Sciences is providing assistance under PMCP Thrust Area 4B to explore novel AFA alloy design with machine learning (ML) (MAT194).

Reviewer 2:
There is excellent collaboration with the PNNL partners for characterization, industry for heats, etc., and the Computational Science Group at ORNL.

Reviewer 3:
This project seems to be fairly well coordinated, with defined roles for each collaborator. The industrial partner, MetalTek International, is currently functioning primarily as a materials vendor. It was not clear how well the parallel ORNL efforts in data analytics and ML were integrated into the material development phase of the project, as this is proposed as future work (it might have been more beneficial earlier on in the process). The analytics work was being carried out under a separate thrust—MAT194— so perhaps results to facilitate such an early integration were not available sooner.

Reviewer 4:
Additional details on contributions from Metal Tek International would help.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
Overall, the project approach is good. It follows the logical development process from modeling the alloy compositions, to synthesis and characterizations, and eventual scale-up. However, one of the key steps that is missing is some sort of techno-economic analysis for the cost and performance of the new alloys and the

comparison to other state-of-the-art alloys. The reviewer wants to know if the alloys being developed will find acceptance by the engine manufacturers. This risk needs to be addressed sometime in FY 2021.

Reviewer 2:
This project is now focused on an exploration of feasibility and scale-up, now that a promising alloy has been down selected. The proposed future work includes a wide range of activities, including sensitivity analysis, castability studies, mechanical property testing to develop an alloy datasheet for the new material, prototype component production, and integration of ML and data analytics to optimize the alloy design (collaborated supported). These are all valuable things to do, but the project team may need to narrow them down to build a cohesive plan for the remaining 1½ years in the project. The team is still developing milestones and a workplan for the final year of the project (milestones past September 2020 are not yet defined). Over the next few months, the team will need to narrow down to focus on the most valuable efforts, since it seems unlikely that all of the proposed research avenues could be pursued- and brought to a satisfactory conclusion- within the final year of the project.

Reviewer 3:
Future research to complete this project will focus on the industrial casting feasibility evaluation. Also, from the collaboration with Thrust Areas 4A and 4B, the team should gain a better understanding of and guide alloy scale up for advanced characterization and computational models (ML, data analytics). Also, if funds and time permit, the project team will attempt to cast a trial component, which will confirm the castability and homogeneity of the material.

Reviewer 4:
The reviewer wanted to know why ML is needed for novel AFA alloy design and what commercial alloys have resulted from ML. The reviewer was not sure what value data correlation and visualization is bringing to the project. Collaboration with materials and automotive suppliers would greatly benefit this project and steer it toward the realities of commercial casting and component production.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The project focuses on lightweighting and material performance improvements under extreme environments and meets the scope of DOE objectives.

Reviewer 2:
This project, focused on developing higher temperature austenitic alloys, supports DOE's goals of increasing the energy efficiency of ICE engines via higher temperature operation.

Reviewer 3:
Yes, this project supports the overall DOE objectives by providing the knowledge needed to develop high performance materials for lower cost, higher efficiency engines and vehicles.

Reviewer 4:
The project supports the DOE objectives for fuel savings. Development of new, high temperature alloys will allow vehicle engines to be operated at higher temperatures and pressures, resulting in increased efficiencies and reduced fuel consumption. In addition, low cost alloys will not impact the overall vehicle costs, as compared to Ni alloys.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This project was completed on schedule and the funding appeared to be sufficient since all of the stated objectives were completed.

Reviewer 2:
The resources appear to have been sufficient for this effort.

Reviewer 3:
Adequate resources were available for the project, including computational, material, and commercial thermodynamic software such as JMatPro and Thermo-Calc.

Reviewer 4:
Resources are sufficient, but a better description as to who is doing what within the collaborator base would be helpful.

Presentation Number: mat185
Presentation Title: Additively Manufactured Interpenetrating Composites (AMIPC) via Hybrid Manufacturing
Principal Investigator: Derek Splitter (Oak Ridge National Laboratory)

Presenter

Derek Splitter, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

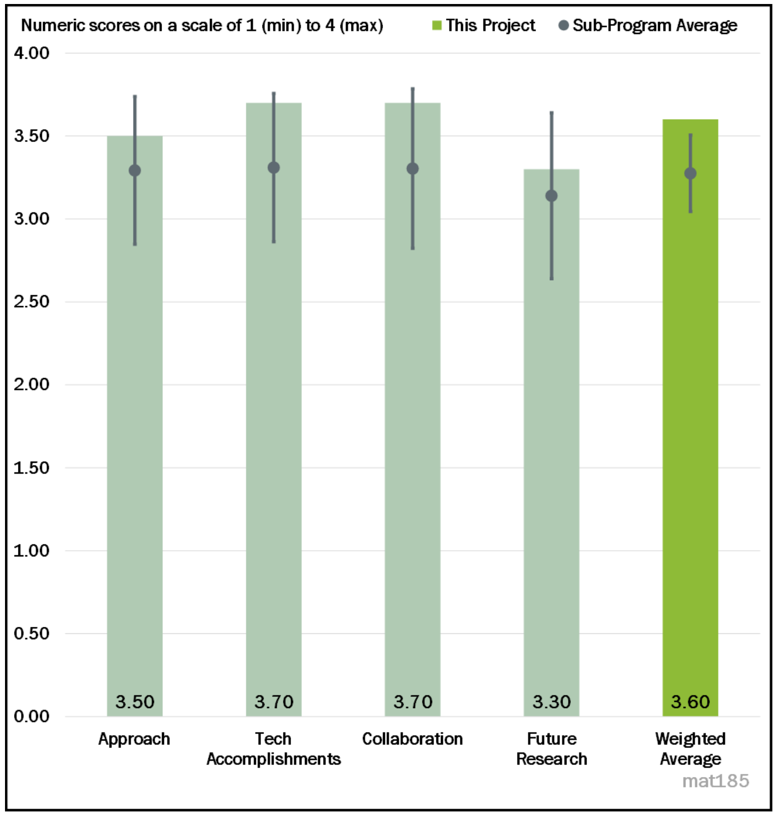

Figure 6-39 - Presentation Number: mat185 Presentation Title: Additively Manufactured Interpenetrating Composites (AMIPC) via Hybrid Manufacturing Principal Investigator: Derek Splitter (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project falls under Subtask 3A2—Hybrid Manufacturing of Additive Manufactured Interpenetrating Phase Composites (AMIPC) of the PMCP in Research Thrust Area Additive Manufacturing of Powertrain Alloys .The approach used to investigate the impacts of many different materials for powertrain use in the PMCP is an excellent strategic tactic to use to leverage limited resources and investigate several potential solutions.

The budget for FY 2020 is $220,000 and the total budget is $1.1 million, which is $220,000 per year for 5 years. The project timeline for this activity is October 2018 through September 2023, and the project is currently 30% complete. This activity is coupled with Thrust Area 4.

The reason for this project is to find material challenges that can withstand and survive high energy impacts on pistons during knock and stochastic pre-ignition (SPI) conditions. To date, conventional material properties have limited material selection. However, heterogenous material systems are a promising technology that may lead to the development of material properties that can withstand these challenging environments.

The approach developed by the PI to obtain these results is to produce multi-metallic components while enabling opportunities for lightweighting. This approach breaks conventional materials tradeoffs and enables new design and efficiency opportunities. To achieve this material property, a hybrid process was used. AM is combined with melt infiltration (molten Al) with advanced characterization. Computer aided design (CAD) and finite element analysis (FEA) characterizes the behavior in the laboratory. A preform is used to strengthen the AM, and the design approach for the FEM includes AM reinforcement, an interface, and the infiltrated matrix for preforming.

This out-of-the-box approach provides the opportunity to develop the materials needs for high compression engines.

Reviewer 2:
There is very good use of modeling (finite element analysis [FEM]), experiments, and advanced materials characterization, and an excellent validation of modeling approach. Novel material properties were achieved by combining new AM potential with traditional casting. The requirements for binding between the printed and cast materials is still unclear, in addition to if the FEM model is considering potential interface failures or just different material properties.

Reviewer 3:
The project is producing very interesting results. The original selection of the lattice geometry and orientation is not clear based on success in other industries, as pointed out in the "reviewer questions" response. The team is deploying the type of evaluation and analyses capabilities that would be expected of a National Laboratory-led project. The identification of future areas of study based on the results being observed shows a very good level of understanding in how to remain flexible in the overall approach while striving toward the stated goals. More emphasis on the failure modes would be extremely instructive. The excellent characterization of the loaded specimens- such as in Slide 6- is not clarified with respect to initiation mechanisms and propagation, although this would appear to be addressed in detailed fashion through the high quality FE simulations.

Reviewer 4:
Obviously, the approach is successful given the improvements, but without more discussion of the underlying science, it is hard to determine whether or not the results are truly optimum. Because the reviewer missed the window of opportunity to ask questions, there are a lot of unanswered questions about the motivation for the approach which the reviewer would have liked to have heard. The reviewer would like to have known how the team decided on a hybrid approach. The reviewer's understanding was that if the approach is a recipe, the team changed the ingredients and changed the amounts of the ingredients but did not change the steps. Also, the reviewer was curious as to why the third parameter was not varied, and if someone has tried this hybrid approach before but with different ingredients. In addition, the reviewer wondered if the team had a reason to think this would not have worked, what the underlying science is, and why the team would be surprised about non-linearity. Given the non-linearity, the reviewer wanted to know if the team could have better explored the area of rapid change.

Reviewer 5:
The reviewer asked for confirmation of the plan view of the piston in order to understand how much of the piston is being reinforced with the lattice and a description justifying this approach to solve this problem. Because the team is creating an expensive technology, why is such a regular lattice produced by an expensive 3-D printing process needed? The lattice is too coarse at a spacing of 2.5 mm. The temperature changes substantially within a millimeter of distance from the surface.

Why could a 316L fiber mat or foam not be used? There are other materials obtained in this form that are much cheaper and have a much smaller inter-fiber reinforcement. Ceramic fiber mats could also be used.

The reviewer noted that bonding of molten Al with 316L is generally poor so there will essentially be a mechanical bond. Is a coating being used? This will add cost as well. Was any modeling done to show how much the heat transfer would be affected with a 40%-50% stainless steel lattice?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The team is demonstrating extremely good progress in the overall presentation of this novel material system for pistons. The combination of fracture characterization, stress analysis through single-prolonged stress (SPS), and detailed FEA provide a clear picture of the behavior and motivation for future work. The optimization of the lattice geometry and orientation appears to be critical and is rightly pointed out as an area of focus based on the results. The ability to adjust these characteristics is endless based on the capabilities of AM, so the future work component is exciting to consider. The damage tolerance issue has multiple other dimensions to consider, not the least of which is a compatible material system in a stressed composite. The team indicates- at least in a cursory fashion- that this is still part of the evaluation matrix and is a consideration that can heavily leverage finite element work for optimization.

Reviewer 2:

There is an outstanding model correlation with the experiments. It is nice to see that samples have been fabricated and testing has been completed at this stage of the 5-year program. The reviewer would like to know if excellent energy absorption makes this material good for structural components to improve crash worthiness.

Reviewer 3:

Progress is excellent because several milestones were completed ahead of schedule, and an order-of-magnitude improvement was seen in the strain tolerance.

Reviewer 4:

The project results to date have found that there is a nonlinear trade off volume fraction of the reinforcement and the infiltrated matrix. Proposed testing materials include (1) Reinforcement: Ti and stainless steel and (2) Infiltrated matrix: Al or Mg. To date, the AM 316L stainless steel reinforcement and the melt A356 Al infiltrated matrix have been tested. The team is using these behaviors to improve design iterations.

De-localized failure mechanisms are under exploration since delocalized damage greatly increases strain to failure. This knowledge is directly applicable to the survivability of brittle piston failures in the ringland area. The investigating team is coupling results to property relations relevant to pistons (thermal conductivity, specific yield strength) to develop new material systems.

A FEA model is being used to develop new material systems, bridging conventional boundaries. Tensile load is only being carried by the AM 316L stainless steel reinforcement. A key factor is that the design of the reinforcement must not surpass the ultimate tensile strength (UTS) to permit transition to high damage tolerance. Lattice geometry optimization is a logical next step in this design process. This approach is being considered for multi-material bonding applications.

Shock loading and fatigue are guiding the future project path. These factors can impact the entire engine design. It is critical to minimize the engine damage caused by shock. It appears that this bi-metallic approach of combining AM and melt infiltration can achieve very high damage tolerances.

Both FY 2020 milestones have been completed ahead of schedule.

Reviewer 5:

Excellent progress has been made as a standalone project in terms of understanding the material. However, the data should be presented in relevance to the requirements of a piston. The benefit in piston applications is strictly related to yield strength, because once there is any deformation, the rings will start to lock up. From this standpoint, only the 50% reinforced material looks better. However, 50% is a huge amount of reinforcement. By the time the material reached the crack bridging phase, the material is of no value to a piston. The reviewer would like to know if the data in Slide 6 are at room temperature, and if so, why it was not at the elevated temperature of 275°C. In addition, the reviewer wants to know why 356 was selected because it is not a piston alloy and encourages the team to use the hypereutectic silicon alloy 390.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There are no apparent shortcomings here. The role of Bechtel is not entirely clear, but progress is being shown and the quality of results indicate that the team is functioning at an appropriate level.

Reviewer 2:
The team appears to have good collaboration with academia and industry. The results are being published and are drawing interest in additional applications outside of vehicle technologies.

Reviewer 3:
The reviewer found the collaboration to be outstanding for multiple reasons: There is an impressive, collaborative publication output,

the company sought the team for work outside the vehicle market, and work is being done with both the MDF and Spallation Neutron Source (SNS).

Reviewer 4:
Partnerships with academia and industry are in place. Rice University (vacuum casting technique development) and Bechtel (industry partner providing project direction advising and the potential for expanded utility) are active participants in this project. The PCMP Task 4 work in crystal plasticity modeling of an Al matrix for optimization opportunities in tension loading is being coordinated with this project. Also, through the PCMP, other National Laboratories are being informed about this activity.

Reviewer 5:
This is an excellent team of well-qualified individuals. Having an OEM support or consult would be of benefit.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
Future work focuses on shock loading and scale-up to a component level. There is interest in using this research in other applications outside of vehicle technologies after releasing some of the findings.

Reviewer 2:
Proposed future research that was presented at a very high level is good. It would be very good to see cyclic load testing and impact testing to understand if there are any detrimental interface effects that large plasticity testing does not identify. No detailed plan with future milestones and decision points is provided, and there is no linkage to a project budget.

Reviewer 3:
This project is hard to judge, as it is only 30% complete. Of course, scale-up is a good idea, but the reviewer would like to have seen discussion of how that might be done to take into account the nonlinear response, in addition to how to optimize the amount by which is should initially be scaled up. Knowing what the team gets with scale-up and why it would be so different from the current scale would be good.

Reviewer 4:
The indication that the team will be looking at optimization of the lattice geometry is one of the key highlights of the proposed future work. Additionally, the suggestion that shock loading and fatigue are next steps will be

critical to the overall study. The fracture patterns in the composites (particularly with respect to interfaces between A356 and 316L) are going to provide an immeasurably level of importance of information regarding the damage accumulation and the ultimate failure mechanisms in this novel system. The shock loading is not as interesting as the fatigue component in the reviewer's opinion. The fatigue cycles in a piston groove build up to extremely high numbers, and the initiation of a crack early in the projected life may prove to be a severe limitation. The team points to "scale up to component level," but no specific mention is made of component testing. The reviewer would like to know if this is planned.

Reviewer 5:
The reviewer asked for an explanation of why a strut and node geometry will provide any difference in the outcome of the material properties with reference to a piston application. What did the project team learn that is making the team choose the three new designs? The key consideration is where the product becomes non-usable; it is not at 20% strain for a product that has to operate at micron tolerances. Are the fatigue properties of the composite system in FEM analysis to be done at the resolution of the finite elements being in the matrix and reinforcement with some criteria for the interface, or will the material be treated as homogeneous?. Please make sure to include the Al piston alloy 390 in baseline calculations.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The role of AM in optimizing component performance in automotive applications is still in its infancy. The team is taking a proven approach and applying it to an automotive problem that potentially enhances resistance to failure under extreme conditions, providing an opportunity for extending the efficiency by facilitating operation at more efficient, but demanding, levels.

Reviewer 2:
Bi-metallics is an interesting area for significant exploration for novel material properties. Significant research is needed, for projects, budget, etc.

Reviewer 3:
Yes, this project supports the overall DOE objectives by providing the knowledge needed to develop high performance materials for lower cost, higher efficiency engines and vehicles.

Reviewer 4:
Improving the performance of internal combustion engines leads to a reduction in energy needed and an improvement in emissions.

Reviewer 5:
Enhancing the ability to lightweight supports DOE's energy efficiency mission, whereas increasing safety does not do this so much, aside from indirectly increasing competitiveness.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The project is making good progress with the stated budget.

Reviewer 2:
Even at a DOE laboratory, $1.1 million should enable a thorough exploration of this area. Given that it is ahead of schedule and already getting great results, the scope might possibly be realistically expanded to include a study of more variables.

Reviewer 3:
This project is on schedule and the funding appears to be sufficient since all of the stated milestones have been completed on time (to date).

Reviewer 4:
There is a good selection of researchers.

Reviewer 5:
Detailed tasks and milestones within the budget were not provided. The reviewer cannot adequately comment on this question. This information seems to be generally lacking from several of the DOE laboratory presentations.

Presentation Number: mat186
Presentation Title: Modeling of Light-Duty Engines
Principal Investigator: Charles Finney (Oak Ridge National Laboratory)

Presenter

Charles Finney, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

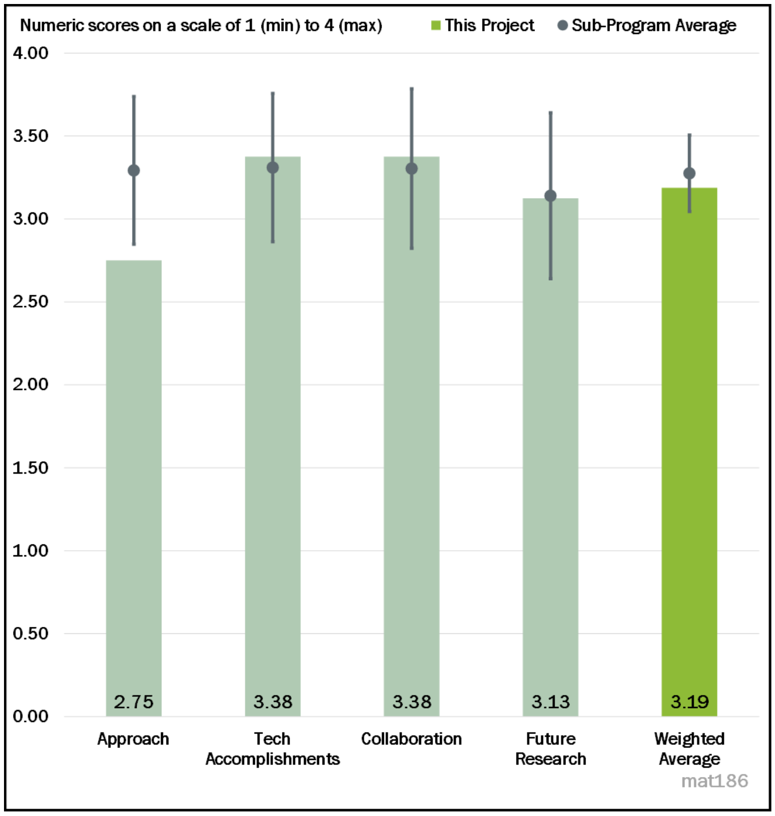

Figure 6-40 - Presentation Number: mat186 Presentation Title: Modeling of Light-Duty Engines Principal Investigator: Charles Finney (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

There is currently a wide range of research works going on related to corrosion and oxidation of automotive engines at ORNL. Using computational and experimental tools, this project is addressing one of the significant components of lightweight engines with high power density materials. This project is divided in two parts. Of the major activities proposed, the first one is to predict and develop new materials for lightweight engines which can operate at extreme conditions such as high temperatures and pressures. The second is to increase the efficiency by reducing emissions and predicting material properties. The third is developing and estimating the affordability of advanced engine materials and components. The fourth is accelerating the time for advanced materials. Lastly, investigators will use the experimental tools for scaling the new alloys for commercial use.

Reviewer 2:

The proposed modeling approach including FEA and computational fluid dynamics (CFD) is good, but there is no clear advantage or difference from the engineering modeling approach practiced in the automotive industry. Due to the lack of the engine data and models from automotive OEMs to be used for DOE-sponsored research, this project has value in providing data and models to support engine materials and process development. However, there seems to be no scientific and technological novelty in this project.

Reviewer 3:

The project appears to duplicate thermal engine and stress modeling work, which is already being done by the OEMs using proprietary methods and targets. Therefore, it is not clear why this simulation effort is needed to set future materials targets. The benefit of this project would be to expose the conclusions of future material needs to the public; however, it is unclear who would take advantage of these conclusions that has not already been given access to them by an OEM seeking superior high temperature material properties. The project also appears to be at a disadvantage because it does not have direct access to the engine CAD, relying instead on a labor-intensive process of building a solid model from a high definition 3-D scan.

Reviewer 4:
The team plans to use mechanical and CDF simulations of engine behavior to establish material property requirements for future lightweight engines. However, the team did not discuss any efforts to determine what the most critical material properties are, nor did the team provide a list of what material properties plan to be investigated. The focus seems to be more on the approach (mesh generation, running the models, etc.) rather than on the objective of determining the material property requirements.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer rates this as a very good proposal and investigators made excellent progress. An excellent strength of this project is the systematic approach to find a material or materials to increase the power density.

Reviewer 2:
The project has generated significant modeling results which can be used to guide materials development and process innovations for high performance engine development.

Reviewer 3:
The project is going about achieving the stated milestones with the best possible method under the apparent intellectual property (IP) restrictions.

Reviewer 4:
The team has made good progress so far.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
From the presentation, it is very clear that the coordination between the investigators is good, and the major research of this project is highly interdisciplinary in character.

Reviewer 2:
There are excellent collaborations within the project team.

Reviewer 3:
Collaboration within ORNL and with Convergent Science, Inc. seems to be fruitful. Two OEMs are said to be involved, but do not appear to be participating in the project at fullest potential. It seems that an enabler for this project would be to partner more extensively with a LD engine OEM to ensure grounding in geometry and method of evaluation.

Reviewer 4:
The collaboration seemed fine.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
Future research seemed reasonable.

Reviewer 2:
The reviewer suggests exploring new simulation methods and approaches, such as ICME, based on location-specific properties.

Reviewer 3:
Investigators made some progress on the project using a systematic approach and they predicted two different materials for the heavy-duty (HD) engine. The reviewer's suggestion is that investigators should check the surface and chemical properties of the materials. The concern is that there is no detail about the computational materials procedure and results.

Reviewer 4:
The project plans to use a finite element simulation process developed for HD cast Fe cylinder heads and applying it to a LD cylinder head currently made of Al. The failure criteria used for a brittle cast Fe should probably not be the same criteria used for ductile Al; however, an appropriate Al failure criterion likely exists.

Setting targets needs to be done with more OEM collaboration than what is stated in this project. The goal of defining future material needs is worthwhile, but without engagement from teams that work on this problem on a routine basis, the effort may yield little new value.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Development of high temperature cylinder head alloys enables higher power density engines and reduced fuel consumption.

Reviewer 2:
The project is highly relevant.

Reviewer 3:
Yes, the project supports overall DOE objectives. High power density material is the key component of the engine performance. New materials are needed for next generation, fuel efficient engine. In this project proposal, investigators explain the systematic approach to find out new materials with high power density. Combining the experimental and computational approach can have a broad impact on the development of a lightweight engine.

Reviewer 4:
This is useful work, but it lacks novelty in the simulation methods.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
There is sufficient funding for modeling work.

Reviewer 2:
Resources appear to be sufficient to complete the stated milestones; however, the milestones only describe activities which will be performed- not deliverables such as new insights which will be gained or key questions which will be answered.

Reviewer 3:
The resources seem fine.

Reviewer 4:

The reviewer's major concern is related the subtask 4B4. Investigators finished only 22% of the project work, and the remaining 78% of the project's future work road map is not convincing to the reviewer.

Presentation Number: mat187
Presentation Title: Fundamental Studies of Complex Precipitation Pathways in Lightweight Alloys
Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

Presenter

Dongwon Shin, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 25% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

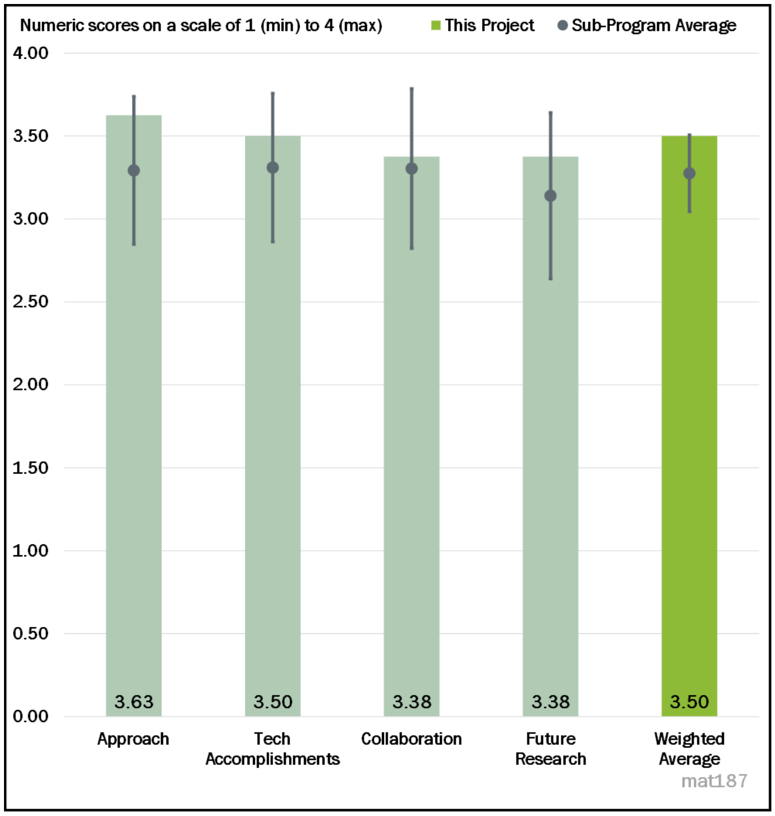

Figure 6-41 - Presentation Number: mat187 Presentation Title: Fundamental Studies of Complex Precipitation Pathways in Lightweight Alloys Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer referenced prior comments.

Reviewer 2:
The project is based on fundamental density functional theory (DFT) calculations to model the interfacial energy and precipitation in Al alloys. The modeling research is also supported by a high quality characterization study.

Reviewer 3:
This project is leveraging the advanced experimental and computational tools available at ORNL and other partner facilities to explore complex precipitation pathways in lightweight alloys.

Reviewer 4:
The approach seems reasonable. Manufacturability should be considered as soon as possible to help identify the best alloy compositions.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Progress is excellent. The reviewer suggests investigators to check the surface and chemical properties of the alloys. If investigators explain the thermodynamics using potential energy surface, then it will be great. The reviewer also requests that the investigators make open source computational tools to further develop the lightweight engine.

Reviewer 2:
The project has achieved the interfacial energy calculations of precipitation, including anisotropy and solute segregation effects. The concept of co-precipitation of L12 and aluminum-copper (Al_2Cu) needs to be reconsidered. CALPHAD analysis suggests that L12 phase forms during solidification before the formation of alpha-Al. So, most likely, L12 promotes grain refinement and perhaps heterogenous nucleation of Al_2Cu during aging.

Reviewer 3:
The team has made good progress and mentioned seeing a given defect in the experiment and then explaining that the researchers had to try out several configurations before the DFT predicted that it was an energy favorable state. The reviewer would like to know if the team has plans to use automated approaches to try out various defect configurations with the DFT to discover low energy defects rather than relying on the experimental data.

Reviewer 4:
Several publications were submitted to share the research results.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
From the presentation, it is very clear that the coordination between the investigators is good, and the major research of this project is of a highly interdisciplinary character.

Reviewer 2:
Collaboration within the project team is evident from the results.

Reviewer 3:
Collaboration and coordination are shown with several other academic institutions and National Laboratories.

Reviewer 4:
Collaboration is fine.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The proposed path will dig into fundamentals and attempt to populate a dataset to train ML.

Reviewer 2:
Proposed future research is fine.

Reviewer 3:
The future research plan is generally sound. It is suggested to include precipitation kinetic modeling using the Kampmann-Wagner (KWN) or other models.

Reviewer 4:
The reviewer’s concern is related to the first principle calculations. Investigators used the high throughput DFT techniques, but there are still no details on how the team predicted vacancy defects in the alloys. If the techniques are different than the cluster expansion model, then the investigators should explain the differences and compare the results with the cluster expansion model.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Understanding precipitation hardening and harnessing its strengthening effects is critically important to the development of lightweight alloys for vehicle lightweighting.

Reviewer 2:
Understanding mechanisms of complex precipitation pathways in lightweight alloys may enable higher temperature alloy development.

Reviewer 3:
The reviewer referenced prior comments.

Reviewer 4:
The relevance is good, as long as overall DOE objectives can be supported.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
So far, resources seem sufficient in supporting the team.

Reviewer 2:
Resources appear to be sufficient.

Reviewer 3:
Resources were fine.

Reviewer 4:
Although investigators made major progress for the development of new materials, there are some concerns about the project. One of the major concerns is related the subtask 1A1. Investigators finished only 30% of the project work, and, for the reviewer, the remaining 70% of the project’s future work road map is not convincing.

Presentation Number: mat188
Presentation Title: Properties of Cast Aluminum-Copper-Manganese-Zirconium Alloys
Principal Investigator: Amit Shyam (Oak Ridge National Laboratory)

Presenter

Amit Shyam, Oak Ridge National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

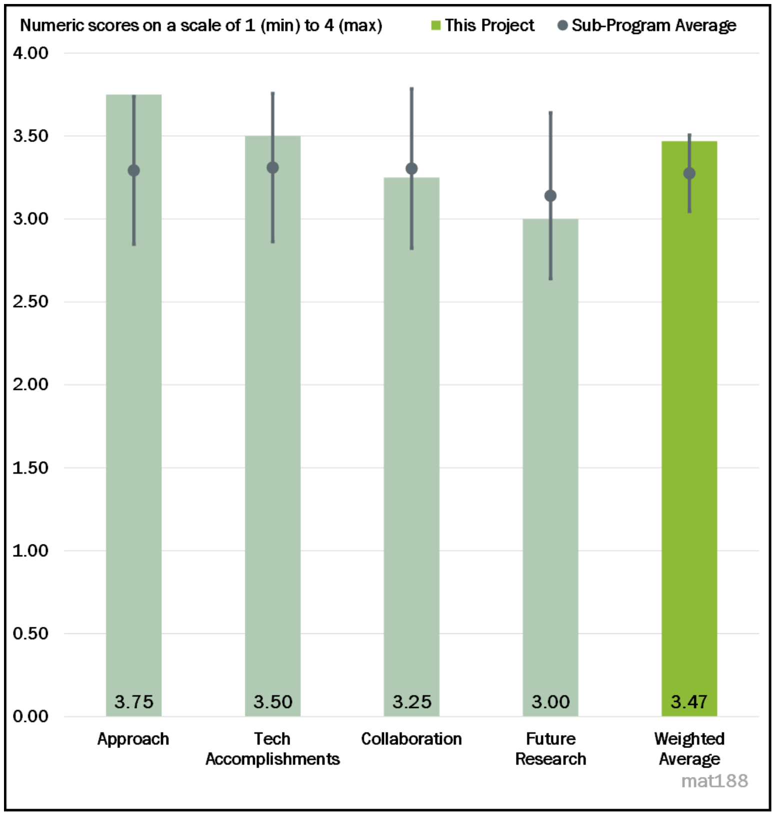

Figure 6-42 - Presentation Number: mat188 Presentation Title: Properties of Cast Aluminum-Copper-Manganese-Zirconium Alloys Principal Investigator: Amit Shyam (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The approach seems solid and well-planned.

Reviewer 2:
Good progress has been made in studying the role of increased copper content on elevated temperature properties. The reviewer agrees that improved properties (yield, ultimate, elongation, and fatigue) at elevated temperatures are very important, but would like to see property targets at a given temperature. This would better allow the team to focus on specific goals.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Overall, the progress seemed reasonable.

Reviewer 2:
Good progress is being made on studying increasing copper levels and correlation to ICME models. Again, a set of targets has not been developed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project seems to be broken down into multiple phases with assigned roles for each.

Reviewer 2:
Not a lot of information was provided about how the group interacts and coordinates. This might be something to discuss more in the future.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The plans seemed reasonable.

Reviewer 2:
The proposed future research statements on Slide 20 are a bit to general. The reviewer would rather see a more task-oriented list. For example, exploring new alloy systems as future research is very difficult to judge. The reviewer would like to know if this is referring to one new system or ten new systems.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This effort addresses the need for improved materials for better internal combustion engine (ICE) performance.

Reviewer 2:
The project does support the DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Team resources appear to be sufficient.

Reviewer 2:
The reviewer had no comments.

Presentation Number: mat189
Presentation Title: Fundamental Development of Aluminum Alloys for Additive Manufacturing
Principal Investigator: Alex Plotkowski (Oak Ridge National Laboratory)

Presenter

Alex Plotkowski, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

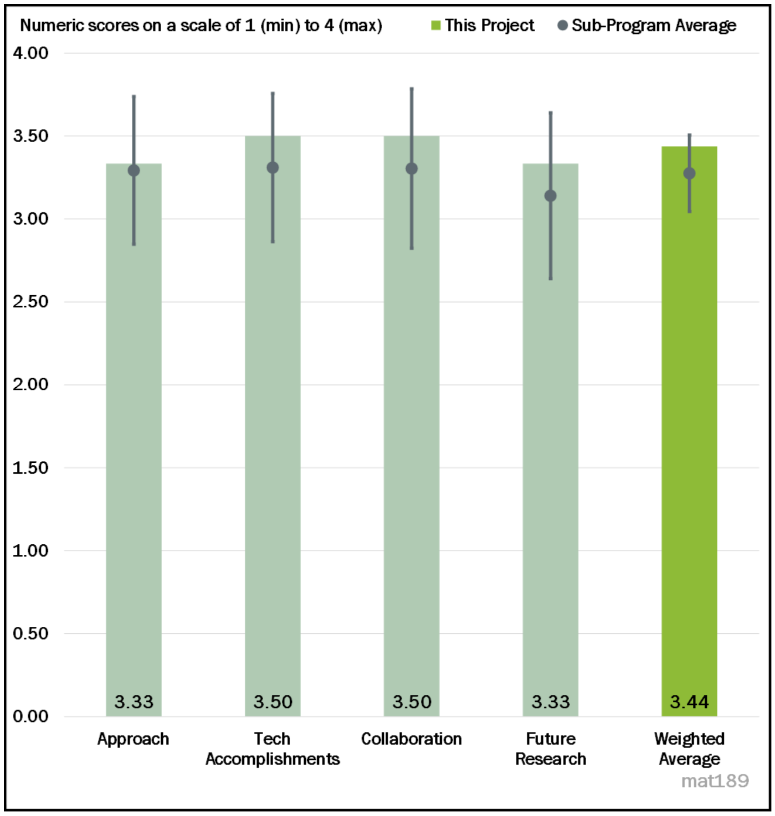

Figure 6-43 - Presentation Number: mat189 Presentation Title: Fundamental Development of Aluminum Alloys for Additive Manufacturing Principal Investigator: Alex Plotkowski (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project is characterized by a highly structured approach, especially the combination of ICME-based alloy design and experimental work that is executed in a model way. Furthermore, all aspects are put into a correct technical and industrial background which proves that this work is rather valuable.

Reviewer 2:

Specific, targeted search regions to minimize hot tearing were identified for exploration.

Reviewer 3:

The reviewer was a bit unclear on the property targets. The reviewer agreed that increased properties are needed at temperatures between 250°C400°C, and that AM can be used to print complex geometries (not possible in castings), but did not see what the targets (yield, ultimate, elongation) are, and at what temperatures.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

So far, accomplishments have been made, especially with regard to success in alloy development, and are on track with the research plan.

Reviewer 2:
The team successfully printed and characterized three new alloys with improved hot tear resistance. The performance of these alloys exceeds the aluminum-silicon-magnesium (Al10SiMg) alloy (except elongation) above 250°C.

Reviewer 3:
The tensile properties of the developed alloys show improved strength retention over commercial alloys at elevated temperatures.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There seems to be good collaboration within the project team and with external collaborators.

Reviewer 2:
Coordination of activities across several university partners is explained well.

Reviewer 3:
There is a large team that seems to be reaching the goals. The reviewer suggests defining a set of target properties at various temperatures, so the team knows when the final goal has been reached.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The team is continuing to develop and print new alloys in 2020, followed by printing prototype parts in 2021, and testing is reasonable.

Reviewer 2:
The focus of the current study is breadth, simple geometry, and characterization. Future work will narrow breadth and scale-up to more product-like geometries with longer term testing (fatigue, creep).

Reviewer 3:
The proposed future research covers the essential blank spots in the current work. A cross-checking of the hot tearing model and its applicability to the chosen processing route is recommended. A point that has not been considered so far is an analysis of the fatigue properties of the newly developed alloys.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
HT Al alloy development with AM capabilities provides opportunities for lightweighting of powertrains as well as increased power density.

Reviewer 2:
Performance enhancement of power train materials for a higher fuel economy of ICE vehicles meets DOE´s targets.

Reviewer 3:
This project does support improved engine efficiency based upon improved elevated temperature properties.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources seem to be on track with the future planned work.

Reviewer 2:
The team is working together to make progress.

Reviewer 3:
Funding appears to be sufficient.

Presentation Number: mat190
Presentation Title: Oxidation Resistant Valve Alloys
Principal Investigator: G Muralidharan (Oak Ridge National Laboratory)

Presenter

G Muralidharan, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

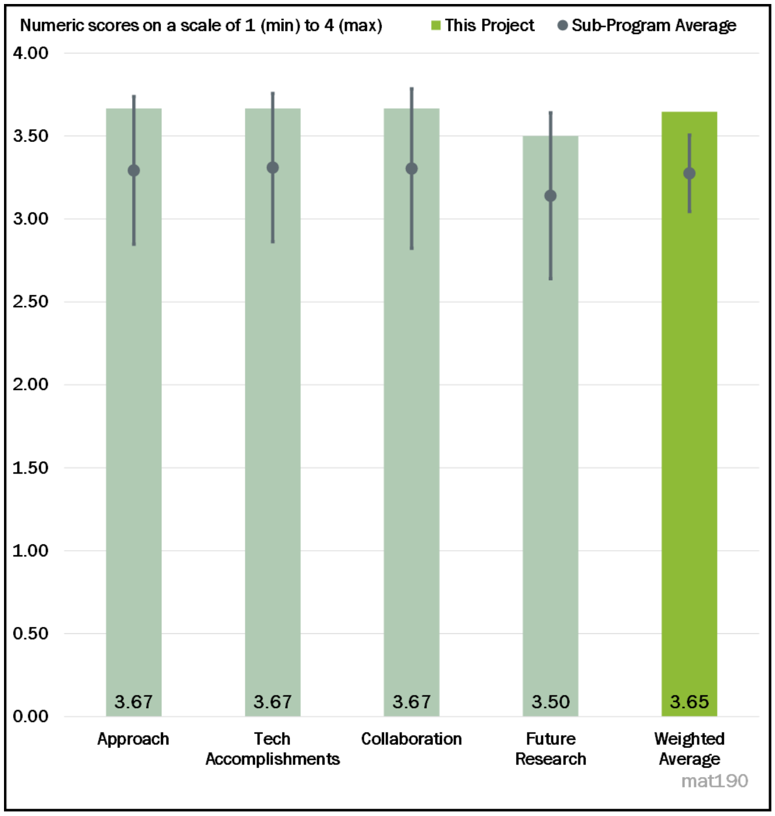

Figure 6-44 - Presentation Number: mat190 Presentation Title: Oxidation Resistant Valve Alloys Principal Investigator: G Muralidharan (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project approach appears feasible and well designed to meet the technical barriers of providing cost effective, higher performance exhaust valve materials to enable higher power density, LD engines. The dual path approach focusing on improving HT strength and oxidation and corrosion resistance by focusing on commercializing lower cost, ORNL-developed chromia forming alloys for use below 900ºC, and developing new, higher strength, lower cost alumina forming alloys for use above 900ºC provides better odds of developing at least one alloy that can meet the needs of high power density engines without increasing the cost.

Reviewer 2:

The project team has presented very remarkable progress on the development of HT strength and oxidation resistant alloys. The approach taken is scientifically and technically sound.

Reviewer 3:

The work appears to be well planned. Good comparison properties are available for existing commercial alloys and good target properties are in place. The target application is well defined, with a temperature range of 900°C-950°C.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The progress made so far appears to be in line with the project plan.

Reviewer 2:
Technical accomplishments are well in line to support project goals, with the ORNL-developed chromia forming alloy 161 (M2045) demonstrating improved performance and a lower cost than commercially available chromia forming alloys. The alumina forming alloy 5B achieved a go/no-go target of 241 megapascals (MPa) at 950^{o}C, while demonstrating good oxidation resistance at 950^{o}C, although long term stability of oxidation behavior of new alumina forming alloys remains to be demonstrated.

Reviewer 3:
Good progress is being made on the new alloy and characterization. There are good target properties in place. Some cost factors are listed, but the reviewer cannot tell how they were developed. The reviewer wondered if they were provided by the OEM partner.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer is satisfied with the collaboration amongst the project team that was presented by the project leaders.

Reviewer 2:
The close collaboration among the project partners has been well coordinated to achieve outstanding results to date. Close collaboration with industry partners should help to ensure commercialization of the new alloys.

Reviewer 3:
The project is broken into tasks that are assigned to the different laboratories and is now moving to work with industrial partners.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
It seems logical to continue to characterize the different development alloys and then follow up with larger casts to produce full scale parts.

Reviewer 2:
The proposed research seems fine. However, in light with the proposed application context as valve alloys, experiments should be conducted to evaluate the oxidation and frictional behavior of the alloys at elevated temperatures.

Reviewer 3:
The project has effectively planned future work to build on successes to date to continue evaluating and improving alloys already developed as part of the project, and to move development toward commercialization scale up. Challenges of scaling up the vacuum induction molding (VIM) process may create a significant risk.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project is in line with DOE`s targets to enhance the efficiency of ICE vehicles.

Reviewer 2:
The project supports the DOE objectives of increasing engine power densities and higher efficiency through the development of higher temperature capability exhaust valve materials and manufacturing processes.

Reviewer 3:
The project supports the DOE goal of improved engine performance through material property improvements and cost reductions.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The team is making good progress and installing new equipment to speed up the effort.

Reviewer 2:
No shortage in resources seems to be apparent.

Reviewer 3:
Resources seem sufficient for the work planned for the rest of the project.

Presentation Number: mat191
Presentation Title: Overview of Advanced Characterization within the Powertrain Materials Core Program
Principal Investigator: Tom Watkins (Oak Ridge National Laboratory)

Presenter

Tom Watkins, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

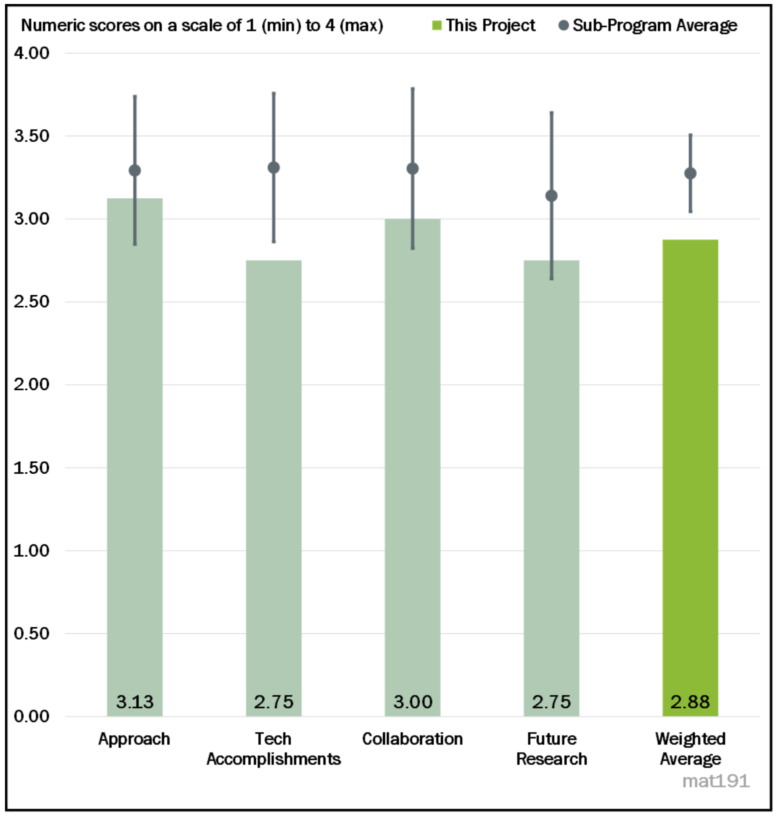

Figure 6-45 - Presentation Number: mat191 Presentation Title: Overview of Advanced Characterization within the Powertrain Materials Core Program Principal Investigator: Tom Watkins (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This is an amazing compilation of the phenomenal experimental and computational capabilities at three DOE labs for advanced characterization with powertrain materials. It appears that the technical barriers, while not specifically addressed (e.g., increasing engine power densities and higher efficiencies) are more likely to be resolved with future novel solutions with all of this capability.

Reviewer 2:

This project falls under Research Thrust Area 4A – Advanced Characterization within the Powertrain Materials Core Program under the Powertrain Materials Core Program (PMCP). The approach used to investigate the impacts of many different materials for powertrain use in the PMCP is an excellent strategic tactic to use to leverage limited resources and investigate several potential solutions.

The budget for FY 2020 is $1.025 million and for FY 2019 it was $1.05 million. The timeline for this activity is October 2018 through September 2023, and the project is currently 30% complete. This activity is coupled with Thrust Area 4B – Advanced Computation within the Powertrain Materials Core Program. ORNL is the lead DOE laboratory for this effort. PNNL and ANL are the other participating DOE labs.

The challenge that this research is addressing is to develop improved powertrain materials with the characteristics needed for increased pressure and increased temperature performance. These materials are needed in new engines that have increased power densities and higher efficiencies. To accomplish this, a need exists to reduce variables to test and reduce development time to develop low cost, high strength materials economically. The development focus for activities under this project falls under is under three thrusts: (1) Cost Effective, Lightweight, HT Engine Alloys; (2) Cost Effective, Higher Temperature Engine Alloys; and (3) AM of Powertrain Alloys. The laboratory team will use a matrix of experts with unique tools, collaboration, and coordination. Projects are selected to understand the fundamentals of these alloys which is needed to optimize materials to maintain performance in harsh environments. Tools at their disposal include ANL's Advanced Photon Source (APS), PNNL's APT, and ORNL's SNS, and allow the project participants to see the alloy trace precipitate. The team can quantify shapes, spacing, and learn how the theta prime and thetas evolve, understanding the transition with respect to time and temperature. Theta prime precipitate provides strength, and an understanding of the transition to the theta phase provides insight into the material performance.

Reviewer 3:
The approach taken seems to be satisfactory.

Reviewer 4:
Although Task 4A: Advanced Characterization includes highly regarded researchers from three National Laboratories—ORNL, PNNL, and ANL—the approach description lacks any substantive descriptions of how the work accomplishes the overall objectives of the PMCP. The ICME component went largely unexplained, and there was little discussion on how the integration of ICME drives the experimental work.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Technical accomplishments are mostly in the applications of the various experimental methodologies to understand metallurgical features (e.g., precipitates) for powertrain materials. It is not clear if any progress has been made toward the development of new materials or the acceleration of alloy development.

Reviewer 2:
Within the project framework, this subproject primarily offers advanced and tailored characterization techniques as a "service" to most other subprojects. It is clear that this entails pushing the boundaries of conventional characterization techniques, which has partly been completed successfully to date.

Reviewer 3:
Since theta prime carries load, the efficient load transfer is identified by using the SNS. Microscopy confirmed that the phase diagrams were predicted by ICME. ICME is a cost-effective approach to the development of new materials for these specialty applications, and significantly reduces development time and cost by identifying materials capable of providing the characteristics needed for specific applications. PNNL's ATS at the Environmental Molecular Science Laboratory (EMSL) user center can investigate HT Ni-based alloys to understand gamma prime, which provides insights into the material strength. ANL's APS – which allows in-situ heating to grow particles in ORNL's Ni valve alloy- was used to understand gamma prime to understand alloy strength. Other project activities include multiphase identification within a creep-ruptured cast alumina forming austenitic alloy conducted by PNNL and ORNL. These results are integrated into the ICME (funded separately through Thrust 5). This characterization of data into ICME, and integrated with ML, is challenging since there is a requirement to keep data formatting and structure consistent to allow for the integration of the data. All FY 2020 milestones have been completed and future milestones are on-track to be completed on time.

Reviewer 4:
A few research examples were given, but the work lacked any grounding within the larger framework of the core program.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration across the three research laboratories is excellent. An industry partner is also participating (Protochips, Inc. located in Raleigh, North Carolina).

Reviewer 2:
The project is particularly designed as to bring together scientific experts from various institutions. This does appear to work quite well.

Reviewer 3:
There is excellent collaboration across the three National Laboratories. The reviewer would like to know what was involved with the ICME that was validated with ORNL's STEM. Was it Calphad only?

Reviewer 4:
Each National Laboratory partner appears autonomous and largely unconnected to the other partners. There is very little collaboration or research integration between the partners. Each partner contributes individually and the need for a team or center-type grant appears unnecessary to accomplish the research goals of the core program.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
An additional emphasis could be placed on how to link experimental characterization techniques to novel approaches in computational materials science.

Reviewer 2:
Targets for the future research are prioritization of advanced characterization requests and developing an integration strategy of the advanced analytical data into the ICME. The integration of data is critical to increase the data library accessible through the ICME. Three separate activities are proposed, each at being led by one of the National laboratories. ORNL will perform in-situ, HT STEM to correlate thin-foil precipitate evolution to bulk material precipitate evolution, and thereby significantly accelerate alloy development and discovery and structures correlated with thin-foil precipitate evolution to bulk material precipitate evolution. This will significantly accelerate alloy development and discovery. ANL will use the Synchrotron for in-situ loading and tomography studies of valve alloys at temperature with a new flexible, in-situ heating and loading system being developed (through Thrust 5 of the PMCP). ANL will also use the Synchrotron to study- through diffraction- the thermal stability of a new, lightweight alloy to help validate the model. PNNL will characterize the microstructure and fine precipitates in developmental piston alloys with advanced STEM.

Reviewer 3:
Seeking Educational Equity and Diversity (SEED) projects were largely proposed, with little discussion of sensibility, risk, and discussion of barriers.

Reviewer 4:
Several times during the presentation, the reviewer heard that there is interest in supporting industry, yet there was no clear path to doing so. The reviewer is not sure where the ultimate value is coming from, from all of this spectacular capability, and would like to know if the focus is mostly on basic research and publications for the benefit of the National Laboratories. If so, this is great, but there are no obvious connections with industry, and this limits the project to more of an academic exercise, almost as if DOE labs have many solutions with no industrial problems driving the need for the solutions. The reviewer would also like to know why no comparative study of neutrons versus synchrotron X-rays for load transform from the Al matrix to theta-prime

precipitates has been conducted, and which is better for this. Such studies would be invaluable for industrial applications. It is unclear where this project is headed, even though there is a slide with proposed future research.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Yes, applications of sophisticated materials characterization and measurement technologies will drive a deeper, fundamental understanding of powertrain materials and add more data for DOE databases.

Reviewer 2:
The project provides fundamental support to a large number of other projects that directly contribute toward DOE´s objectives.

Reviewer 3:
Yes, the project is supportive of DOE objectives in that it provides characterization and a detailed atomic scale analysis of materials and alloys systems that are deemed important to DOE, largely in the area of lightweighting.

Reviewer 4:
Yes, this project supports the overall DOE objectives by providing the knowledge needed to develop high performance materials for lower cost, higher efficiency engines and vehicles.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources are sufficient.

Reviewer 2:
There is no indication as to a shortage in resources that have been given.

Reviewer 3:
The resources appear to be sufficient to support the milestones in a timely fashion. No resource shortfalls were noted.

Reviewer 4:
This project is on schedule and the funding appears to be sufficient since all of the stated milestones have been completed on time (to date).

Presentation Number: mat192
Presentation Title: Fundamentals of Austenitic Alloys via Additive Manufacturing
Principal Investigator: Sebastien Dryepondt (Oak Ridge National Laboratory)

Presenter

Sebastien Dryepondt, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

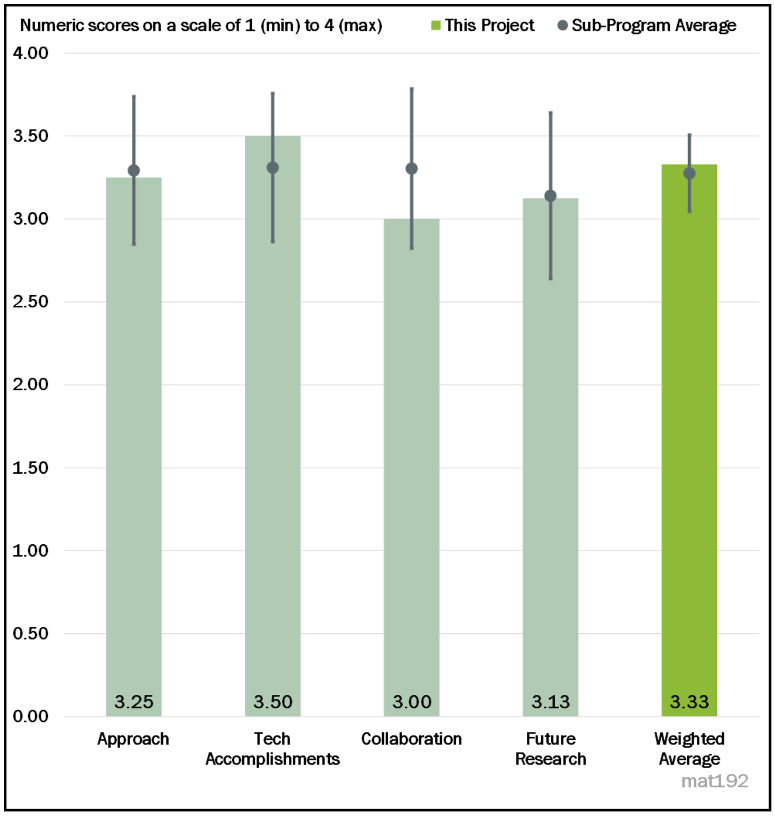

Figure 6-46 - Presentation Number: mat192 Presentation Title: Fundamentals of Austenitic Alloys via Additive Manufacturing Principal Investigator: Sebastien Dryepondt (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

A very clear approach to the development of austenitic alloys fabricated by AM was provided. This approach included a close integration between ICME techniques coupled with high throughput and advanced characterization. The project was very well laid out and progress made to date has been positive.

Reviewer 2:

The approach taken complies with the project plan and shows sufficient aspects of novelty (for example, the high throughput screening). The results described are well characterized.

Reviewer 3:

Some, but not all, of the technical barriers have been addressed (for example, higher power density, higher efficiency engines, costs of engine materials, development time, scaling to commercialization).

Reviewer 4:

The approach described in the presentation is for the initial experimentation and does not directly address most of the DOE technical barriers described on the overview slides (new alloys for higher power density, higher efficiency engines, cost of advanced engine materials, development time and cost of new materials, scaling new materials technologies to commercialization). The approach addresses the first steps of experimentation to collect data on mechanical properties of alloys, which could address the barrier of no HT data and fast screening of austenitic alloys (as well as leveraging microstructure data from another project) and the development of models using FEA and thermodynamic analysis, but not all the barriers to AM of austenitic alloys (cost and scaling barriers for AM and development time). The approach presented was for experimentation and not for the total project, which will address all barriers. The experimental approach is well designed and feasible since it is a standard approach, but differs only in that it addresses specifics of the AM technology being developed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The AM-route demonstrated shows remarkable properties for commercial alloys, which represents a major achievement.

Reviewer 2:
The barriers were clearly defined, and the project has made significant progress, while only midway through the timeline on the objectives and goals. Several "firsts" and notable technical accomplishments were described, indicating good technical progress.

Reviewer 3:
There were good technical accomplishments made using the laser powder bed fusion (LPBF) technique, which produced results for a stainless-steel alloy having very few defects and grains slightly elongated along the build direction. However, the strength at the higher temperatures was lower than expected, possibly due to the stability of the cellular structure. This result is still important for modifying the technique to get a better consistency in the alloy, which should improve the mechanical properties. There were excellent simulation results for thermal cycling and for phase change experiments. The screening experiments also produced particularly good results because no cracks were observed in the test samples, large carbides typical with cast processes disappeared, and clear cellular structures were observed, which demonstrates an effective process. The project also accomplished a "first" for fabrication of a high carbon content alloy using an AM approach. The microscopic analysis confirming the formation of precipitates that strengthen the molecular structure of the alloy was a significant accomplishment for a new material with the potential for HT engine applications.

Reviewer 4:
Technical accomplishments are mainly in the development of the new LPBF HK30Nb alloy that was developed. The reviewer would like more information on whether this can be scaled up for cost effective manufacturing in large quantities.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This task is one of many tasks for early stage research for the PMCP and, as such, its success relies heavily on internal collaboration with the other ORNL researchers working on the other tasks and close coordination between the PIs to leverage data from one another's experiments. This task is already using microstructure data and microscopic analyses from two other tasks, which is an example of excellent coordination.

Reviewer 2:
This appears to be mostly an ORNL-centric project. However, the reviewer applauded the project for seeking industrial collaboration.

Reviewer 3:
Sufficient collaboration has been outlined in the report.

Reviewer 4:
The major weak point in this research project was the lack of industry partners. Also, the connection to the larger core program is unclear.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The proposed future research aligns well with the project goals and DOE objectives. The research that was described appears appropriate, manageable, and with minimal risk.

Reviewer 2:
The proposed research seems to be sound for targeting a deeper understanding of the characteristics of the investigated alloys. Additional emphasis could be placed on the oxidation behavior in light of the target applications.

Reviewer 3:
The proposed future research is just a continuation of the current research into the next budget period. The proposed work follows a logical progression for obtaining additional data to be used with the models. There were no other challenges, barriers, or risks identified in the presentation or by the presenter, nor were any alternate development pathways addressed.

Reviewer 4:
It is unclear how the future research will lead to overcoming some of the stated barriers: higher efficiency engines resulting in increasingly extreme materials demands, costs of engine materials, development time, and scaling to commercialization.

Does the ICME effort only involve Calphad calculations? If not, what else is required to address relevant multi-length scale phenomena? Also, the reviewer asserted that the project seems interested in flow behavior, so how will ICME use a microstructure-based model to predict flow behavior, creep, fatigue, etc.? This cannot be done with thermodynamic predictions alone.

How do non-equilibrium solidification conditions impact mechanical behavior? How do small scale features like cells and precipitates affect macroscopic-scale behavior? How are single track alloy experiments leading to alloys that can be manufactured in a cost-effective manner on a commercial scale? Stainless steel is expensive. Why not try something like 4140?

According to the reviewer, another issue that is not addressed in this project that should be looked at is increasing part through-put with AM. Are 500,000 AM machines really needed to make 1 million parts (for example)? AM is not cost effective for high volume production and is currently limited to low volume applications.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This task supports the overall VTO PMCP which directly supports the DOE objectives to meet requirements for materials needed to develop cost effective, highly efficient, and environmentally friendly next-generation, heavy and LD powertrains to include improved powertrain thermal efficiency, and increased power density resulting from high-strength and lightweight materials.

Reviewer 2:
New alloy development for the extreme conditions in powertrain applications supports the overall DOE objectives.

Reviewer 3:
The project results help to increase vehicle efficiency.

Reviewer 4:
Yes, the project supports the DOE objectives in the rapid development of high-performance metals for HT automotive engine applications.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The approximate $200,000 per year for the 5-year performance period is considered sufficient to support the laboratory staff involved in the early stage research to develop a new, HT alloy using an AM approach.

Reviewer 2:
The resources are okay, but the project lacks industrial involvement to provide much-needed focus and direction.

Reviewer 3:
No limitations were reported.

Reviewer 4:
Resources appeared to be sufficient to complete the project objectives. The project appears to be ahead of schedule.

Reviewer 5:
The resources are okay, but the project lacks industrial involvement to provide much-needed focus and direction.

Presentation Number: mat193
Presentation Title: Higher Temperature Heavy-Duty Piston Alloys
Principal Investigator: Dean Pierce (Oak Ridge National Laboratory)

Presenter

Dean Pierce, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

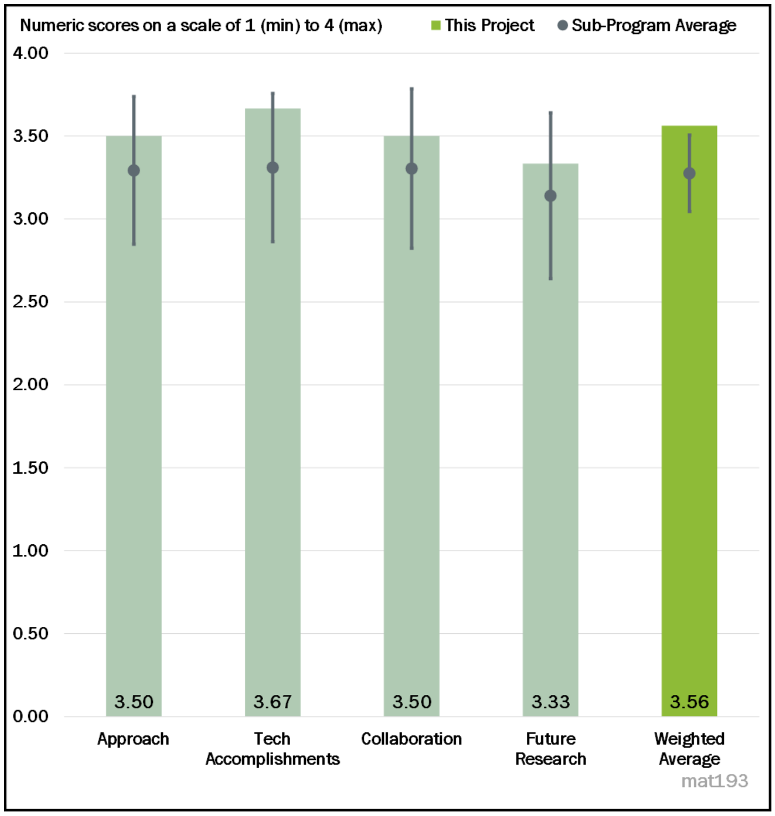

Figure 6-47 - Presentation Number: mat193 Presentation Title: Higher Temperature Heavy-Duty Piston Alloys Principal Investigator: Dean Pierce (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer is fully satisfied with the approach taken by the project leaders.

Reviewer 2:

This project falls under Subtask 2A-2—Higher Temperature Heavy Duty Piston Alloys in Research Thrust Area 2—Cost Effective Higher Temperature Engine Alloys in PMCP. The approach used to investigate the impacts of many different materials for powertrain use in the PMCP is an excellent strategic tactic to use to leverage limited resources and investigate several potential solutions. This project is assessing higher temperature, heavy duty piston alloys for compression ignition engines.

The FY 2019 budget was $250,000, and the FY 2020 budget is $200,000. The period of performance for this project is October 2018 – September 2023 and the work is 30% complete. The project aligns with the PMCP timeline.

Current HD diesel materials (HDD) piston steels (4140 and micro alloyed steel [MAS]) are not suitable for temperatures greater than 500°C have issues with oxidation and fatigue failure above 500°C. The objective of the project is to develop affordable, innovative, higher temperature piston alloys for this application. Developmental material targets for this application are as follows: design for operation between 600°C-800°C; yield strength of 400 MPa at greater than or equal to 600°C; ultimate tensile strength (UTS) of 525 MPa at greater than or equal to 600°C; cyclic oxidation resistance at peak temperatures, in air, and in a water vapor environment; long term microstructural stability; and affordable and manufacturable material.

Reviewer 3:
The approach described in the presentation is for the initial experimentation and does not directly address most of the DOE technical barriers described on the overview slides (higher power density, higher efficiency engines, cost of advanced engine materials, development time and cost of new materials, scaling new materials technologies to commercialization). The experimental approach described is well designed and feasible because it considers evaluation of existing commercial steels at very high temperatures, evaluation of novel and developmental martensitic steels, and the development of low, medium, and high Cr steels to develop novel alloying strategies that will meet requirements for HT engine components at lower costs. This is a good approach to address the technical barriers of accelerating alloy development time, improving elevated temperature strength, and maintaining oxidation resistance.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The technical accomplishments were outstanding for exceeding the strength and oxidation resistance requirements for alloys above 550°C-600°C, which met the performance indicator described in the milestone chart. The results showed that the research was sharply focused on the critical barriers of improving strength at elevated temperatures for novel, low Cr alloys, and maintaining oxidation resistance at high temperatures for medium Cr alloys comparable to or better than commercial alloys.

Reviewer 2:
The reported achievements regarding the novel alloy developments are on par with the targets set out in the project plan.

Reviewer 3:
The team is on track to meet the projected material development targets. Research is attempting to find a lower cost material than the currently available high cost, high alloy content material. A variety of novel developmental martensitic steels with a range of Cr content will be investigated because lower Cr content is lower cost, but also lower performance. Oxidation is a problem with lower cost, lower Cr content steels. To establish a baseline for these materials, alloy 4140 was assessed and compared to commercial 12% Cr by weight (12Cr). 12CR has superior strength to alloy 4140; however, strength drops after long term thermal aging. Oxide intrusion and spallation in alloy 4140 is bad, but trying to avoid it leads to cracks which occurred at 500°C-550°C. 12Cr had unwanted breakaway Fe oxidation occurring at 550°C.

To address these issues, novel alloying strategies were employed, which may lead to improved oxidation resistance and strength at a limited extra cost. For the medium Cr alloys, the strength met targets as tempered. Using novel alloying strategies, the first iteration had good oxidation resistance but poor strength. The second iteration using a novel alloying strategy improved the strength and maintained oxidation resistance at 550°C, and a 600°C test is ongoing. The third iteration of a medium Cr alloy using novel alloying strategies is underway.

The team leveraged an activity performed under Thrust Area 4A to understand that the performance of integrating large Cr carbides into 12Cr steel provided minimal strengthening. It should be noted that the researchers cannot disclose the specific systematic alloy changes because of IP restrictions. All FY 2020 milestones have been completed and future milestones are on track to be completed on time.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This task is one of many tasks for early stage research for the PMCP, and, as such, its success relies heavily on internal collaboration with the other ORNL researchers working on the other tasks and close coordination between the PIs to leverage data from one another's experiments. This task coordinated to use microscopic

analyses from one other task, which is an example of good coordination within ORNL for the overall program. Other tasks may need to be coordinated, as this project progresses to leverage data from the other tasks.

Reviewer 2:
There is particularly good collaboration with partners providing sound and high-quality characterization techniques that exist.

Reviewer 3:
Collaboration across the three research laboratories is excellent. Collaboration is avoiding additional research costs. Industry participant is involved but not identified because of the IP agreement with the laboratory.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The proposed research seems to be straight forward.

Reviewer 2:
A further understanding of the mechanisms resulting in improved strength and oxidation resistance in lower cost alloys is needed. Also, future research will scale up material to larger sizes. The team will investigate more thins and will utilize testing that is more relevant to industrial production and will begin to look for production partners.

Manufacturability of the alloys is still unknown; machinability testing will occur later in the project. There are also different melting practices for the baseline material. Cr alloys are vacuum arc re-melted (VAR), and alloy 4140 is air melted. These processes may impact the manufacturability and forgeability of these materials and will be investigated.

Reviewer 3:
The proposed future research is just a continuation of the current research into the next budget period. The proposed work follows a logical progression for obtaining additional data for scaling up the novel alloys to larger sizes for different types of testing, such as performing more relevant tests, including long term oxidation and elevated temperature fatigue testing simulating engine conditions. The proposed future work also includes establishing collaborations with industry partners to begin addressing barriers to commercialization of new alloys. The remaining challenges and barriers for increased oxidation performance of low and medium Cr alloys are achieving lower costs, fully understanding the mechanisms resulting in improved strength and oxidation resistance in those alloys, and investigating the manufacturability of developmental alloys by studying their melting practice and forgeability. All these efforts contribute to overcoming the DOE program challenges and barriers.

No risks or alternated development pathways were addressed, but the project approach tends toward a low or medium risk for new alloy development.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This task supports the overall VTO PMCP, which directly supports the DOE objectives to meet requirements for materials needed to develop cost effective, highly efficient, and environmentally friendly next-generation HD and LD powertrains to include improved powertrain thermal efficiency, and increased power density resulting from high strength and lightweight materials.

Reviewer 2:
The work described helps to improve the efficiency of vehicle combustion engines.

Reviewer 3:
Yes, this project supports the overall DOE objectives by providing the knowledge needed to develop high performance materials for lower cost, higher efficiency engines and vehicles.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The approximate average cost of $300,000 per year for the 5-year performance period is considered sufficient to support the laboratory staff involved in the early stage research to develop a new HT, low-cost alloy for engine applications.

Reviewer 2:
This project is on schedule and the funding appears to be sufficient because all of the stated milestones have been completed on time (to date). Through the collaboration, the team avoided duplicate research and additional costs.

Reviewer 3:
No deficiencies in resources were mentioned by the project leaders.

Presentation Number: mat194
Presentation Title: Accelerated Design of Alumina-Forming, High Temperature Austenitic Alloys
Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

Presenter

Dongwon Shin, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers indicated that the resources were sufficient, 20% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

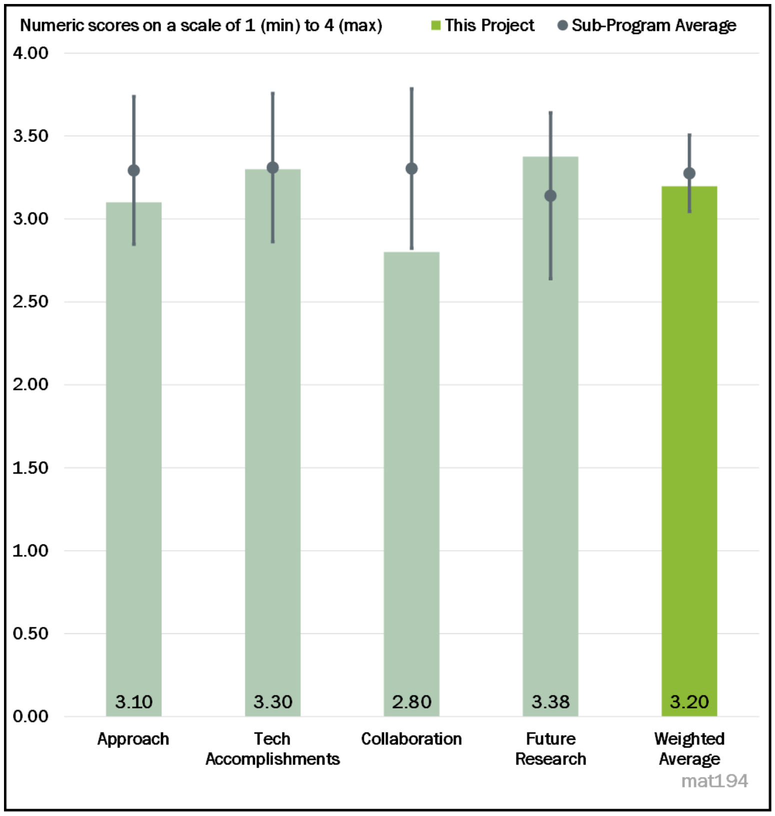

Figure 6-48 - Presentation Number: mat194 Presentation Title: Accelerated Design of Alumina-Forming, High Temperature Austenitic Alloys Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The project uses Thermo-Calc software in concert with ML algorithms to predict the performance of alumina forming alloys. The ML approach was trained using data already available at ORNL. The approach was logical and sound.

Reviewer 2:
Two million hypothetical AFA alloy compositions have been explored. Since validation is virtual, it seems that no new alloys have actually been predicted and discovered since none have actually been made at any scale in a laboratory or elsewhere. This project needs to be coupled to a materials manufacturer who can validate the predictions by actually making the alloys. The project will have limited value if there is only laboratory-scale production in small quantities.

Reviewer 3:
The team made excellent use of ICME and ML to identify potential alloy concepts, but the reviewer would like to know who owns these potential new alloys for industrialization.

Reviewer 4:
It is very fortunate that a decade of creep data is available, and it is brilliant to think of using it with ML; however, the reviewer was disappointed in the limited amount of information being drawn from and augmented to the dataset on Slide 14. Also, the reviewer does not get any sense of the uncertainty error in the data and how uniform the data collection had been over 10 years. The high throughput data analytics

approaches seemed to be outstanding and state of the art; however, the reviewer would like to have seen more data quality analysis for “garbage in, garbage out.”

Reviewer 5:
It is difficult to assess the approach, as the project is in its early stages. It appears that only true validation of the model will occur when experiments are performed in the “predicted to be better AFA alloys.” Overall, the approach appears to be fairly forced since the data set used to train the models was fairly extensive, especially for creep data. It is unclear if a physics-based approach that utilizes microstructural evolution in relation to creep performance would have yielded similar outcomes. This main criticism is of the approach and not of the effort. The work appears to be well designed, but feasibility is still unknown.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Significant progress has been made, given that the project is only 1 month into its start. However, the most significant barrier will be to assess the accuracy of the model, which has not been done yet.

Reviewer 2:
The project has made significant accomplishments in its short duration. The trained ML algorithms have identified several alloy compositions with the potential to meet the target properties. This completes the key milestone for the project. The next task—probably as a continued work—is to produce some alloy compositions in the laboratory and perform tests to validate the performance.

Reviewer 3:
The project is a 1-year exploratory effort and 20% is complete. Targeted completion is September 2020. The team demonstrated ML accelerated design of hypothetical AFA-type alloys and leveraged 10 years of creep data. The team also coupled high throughput computational thermodynamics with ML and trained for prediction of creep resistance.

Reviewer 4:
Several alloy concepts were identified. The researcher will be interested in experimental results, well the results agree with the ML identified alloys, and is looking forward to next year’s presentation.

Reviewer 5:
The results did not seem nearly as clear to the reviewer as the text indicated. Again, without understanding of uncertainty, the results are hard to judge, especially only 20% into the project. For example, the statement that the linear fits are showing good performance does not seem to be supported by the data. Also, the Larson-Miller Parameter (LMP) factor seems to be the main parameter explored.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There was outstanding collaboration within several divisions within ORNL (computational sciences and materials science) and the commercial software developer, Thermo-Calc.

Reviewer 2:
The only industrial collaborator is the Thermo-Calc software company. The reviewer does not see any industry collaborators of the end product and is not sure who owns these new alloys.

Reviewer 3:
It is hard to expect much from a relatively small project, but the use of a particular software seems an odd measure of collaboration.

Reviewer 4:
The collaboration partner activities are unclear. The PI appears to mainly be a user of the software and computing facility. The reviewer would like to know the specific contributions that have come from Thermo-Calc and the Compute and Data Environment for Science (CADES), other than accessibility. The collaboration role of ORNL will be clearer when the experimental components of the program are completed.

Reviewer 5:
The reviewer is not sure of the extent of collaboration with Thermo-Calc as a company as opposed to ORNL just using the software. This project needs to be coupled to a materials manufacturer who can validate the predictions by actually making the alloys.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has

Reviewer 1:
The reviewer is very pleased to see uncertainty quantification to assign error bars of ML predicted LMPs by considering the different number of features for a given ML model. The reviewer just wishes it had been done first.

Reviewer 2:
The proposed future research focuses on experimental validation and verification. These are necessary steps to establishing the fidelity of ML approaches, and thus the proposed future research is appropriate and effectively planned.

Reviewer 3:
Future research should focus solely on making one or more of the hypothetical alloys derived from the simulations and then demonstrating that as the as-made alloys with the desired creep properties. More details are needed on how a favorable alloy will be synthesized experimentally and then tested to demonstrate the desired creep properties. The reviewer would like clarification on who will do the testing.

Reviewer 4:
The project has ended.

Reviewer 5:
Limited details have been provided.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This meets DOE's objective for improved engine efficiencies for vehicles for fuel savings. One approach is to operate the engines at HTs and pressures, which requires HT alloys with enhanced mechanical properties (i.e., creep). In this regard, this project provides a ML approach to identify alloy compositions that have the potential to meet the desired target properties.

Reviewer 2:
If the team is successful in predicting the creep performance of new, never previously developed alloys is shown, the research will have made a significant impact on the community.

Reviewer 3:
The development of lightweight, creep resistance alloys supports the overall DOE objectives.

Reviewer 4:
Improved HT properties of materials are critical to pushing engine efficiencies higher.

Reviewer 5:
HT materials are related to energy efficiency and reducing development time is related to industrial competitiveness.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources seem well matched to the tasks being undertaken.

Reviewer 2:
The resources appear to be sufficient to complete the milestones in a timely fashion.

Reviewer 3:
Computational resources were adequate for the project. In addition, the data set for the alumina forming alloys were available and used for training of the ML models.

Reviewer 4:
The reviewer assumed resources are okay, as no issues were raised, but no details on the plan and budget were provided.

Reviewer 5:
More details are needed on resources required to synthesize the most favorable alloy or alloys from the model predictions.

Acronyms and Abbreviations

2-D	Two-dimensional
3-D	Three-dimensional
4X	4X Technologies
12Cr	12% chromium by weight
μ DIC	Microscopic level DIC
A356	356 aluminum
ABL	Acrylonitrile butadiene lignin
ACE	Advanced combustion engine
ACP	Advanced Carbon Products
AFA	Alumina-forming austenitic
AGC	Aluminum graphene composite
Al	Aluminum
$Al_{10}SiMg$	Aluminum-silicon-magnesium
Al_2Cu	Aluminum-copper
Al_2O_3	Aluminum oxide
AM	Additive manufacturing
AMC	Aluminum matrix composite
ANL	Argonne National Laboratory
APS	Atmospheric Plasma Solutions
APS	Advanced Photon Source
APT	Atom probe tomography
ASM	American Society for Metals
AZ31B	Aluminum and zinc magnesium alloy
$BaTiO_2$	Barium titanate
Bio-ACN	Bio-acrylonitrile
Ca	Calcium
CAD	Computer aided design
CADES	Compute and Data Environment for Science

CAE	Computer-aided engineering
CALPH	CALculation of PHAse Diagrams
Ce	Cerium
CE	Coulombic efficiency
CF	Carbon fiber
CFD	Computational fluid dynamics
CFRC	Carbon fiber reinforced composites
CFRP	Carbon fiber-reinforced polymer
CFTF	Carbon Fiber Technology Facility
CNT	Carbon nanotube
CO_2	Carbon dioxide
CO_2-AP	CO2-atmospheric plasma
CPEC	Close proximity electromagnetic carbonization
CRADA	Cooperative research and development agreement
CRS	Cold-rolled steel
Cr_2O_3	Chromium (III) oxide
CTE	Coefficient of thermal expansion
CTP	Coal tar pitch
Cu	Copper
DARPA	Defense Advanced Research Projects Agency
DFT	Density functional theory
DIC	Digital image correlation
DOE	U.S. Department of Energy
EDX	Energy-dispersive X-ray
EG	Electrogalvanized
EMSL	Environmental Molecular Science Laboratory
EV	Electric vehicle
Fe	Iron

FE	Finite element
FEA	Finite element analysis
FEM	Finite element analysis
FSE	Friction stir extrusion
FSP	Friction stir processing
FSW	Friction stir welding
FY	Fiscal year
GHG	Greenhouse gas
GM	General Motors
H2O	Water
HAADF-STEM	High annular dark field scanning transmission electron microscopy
HCF	High-cycle fatigue
HD	Heavy duty
HDD	Heavy duty diesel
HEDM	High-energy diffraction microscopy
HCP	High performance computing
HP-RTM	High-pressure resin transfer molding
HT	High temperature
IACMI	Institute for Advanced Composites Manufacturing Innovation
IACS	International Annealed Copper Standard
lb	Pound
ICE	Internal combustion engine
ICME	Integrated computational materials engineering
IDZ	Interdiffusion zone
ILSS	Interlaminar shear strength
IP	Intellectual property
kp	Parabolic rate constant
ksi	Kilopound per square inch

KWN	Kampmann-Wagner
LD	Light duty
LMP	Larson-Miller Parameter
LPBF	Laser powder bed fusion
MAS	Micro alloyed steel
MD	Molecular dynamics
MDF	Manufacturing Demonstration Facility
Mg	Magnesium
$MgCO_3$	Magnesium carbonate
MgO	Magnesium oxide
MIT	Massachusetts Institute of Technology
ML	Machine learning
mm	Millimeter
MMC	Metal-matrix composites
MPa	Megapascals
Msi	Million pounds per square inch
NERVE	Networked Elements for Resin Visualization and Evaluation
Ni	Nickel
NiCr	Nichrome
NO_x	Oxides of nitrogen
O_2	Oxygen
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PAN	Polyacrylonitrile
PF	Phase field
PI	Principal Investigator
PMCP	Powertrain Materials Core Program
PNNL	Pacific Northwest National Laboratory Pacific Northwest National Laboratory

PP	Polypropylene
ppm	Parts per million
PμSL	microstereolithography
psi	Pounds per square inch
PSU	Penn State University
Q	Quarter
Ra	Roughness average
R&D	Research and development
ReaxFF	Reactive force field
REE	Rare earth element
RIM	Reaction Injection Molding
ROI	Return on investment
RSW	Resistance spot weld
RT	Room temperature
RTM	Resin transfer molding
s	Second
SAE	Society of Automotive Engineers
SBIR	Small Business Innovation Research
SECCM	Scanning electrochemical cell microscopy
SEED	Seeking Educational Equity and Diversity
SEM	Scanning electron microscope
ShAPE™	Shear Assisted Processing and Extrusion
SiC	Silicon carbide
SIMS	Secondary ion mass spectroscopy
SPI	Stochastic pre-ignition
SPR	Self-pierce rivet
SPS	Single-prolonged stress
Sn	Tin

SNS	Spallation Neutron Source
SRI	Southern Research Institute
SStAC	Stainless steel alloy corrosion
STTR	Small Business Technology Transfer
SuRF	Scale-up Research Facility
T6	Temper 6
TCR	Temperature coefficient of resistance
TEM	Transmission electron microscopy
Tg	Glass transition temperature
Ti	Titanium
TiB_2	Titanium diboride
TiO_2	titanium dioxide
TL	Trifunctional linker
TRL	Technology readiness level
TuFF	Tailored universal Feedstock for Forming
UCLA	University of California, Los Angeles
UD	University of Delaware
µm	Micrometer
UM	University of Michigan
USW	Ultrasonic welding
UTK	University of Tennessee, Knoxville
UTS	Ultimate tensile strength
UW	University of Wyoming
VAR	Vacuum arc re-melting
VIM	Vacuum induction molding
VT	Virginia Polytechnic and State University
VTO	Vehicle Technologies Office
WRI	Western Research Institute

WPI	Worcester Polytechnic Institute
XPS	X-ray photoelectron spectroscopy
YS	Yield strength
Zn	Zinc
ZnPhos	Zinc phosphating
ZrO_x	Zirconium sub-oxide

7. Technology Integration

The Vehicle Technologies Office (VTO) has a comprehensive portfolio of early-stage research to enable industry to accelerate the development and widespread use of a variety of promising sustainable transportation technologies. The research pathways focus on fuel diversification, vehicle efficiency, energy storage, and mobility energy productivity that can improve the overall energy efficiency and efficacy of the transportation or mobility system. VTO leverages the unique capabilities and world-class expertise of the National Laboratory system to develop innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures; and energy efficient mobility systems. VTO is uniquely positioned to address early-stage challenges due to strategic public-private research partnerships with industry (e.g., U.S. DRIVE, 21st Century Truck Partnership) that leverage relevant expertise. These partnerships prevent duplication of effort, focus DOE research on critical R&D barriers, and accelerate progress. VTO focuses on research that industry does not have the technical capability to undertake on its own, usually due to a high degree of scientific or technical uncertainty, or that is too far from market realization to merit industry resources.

The Technology Integration (TI) subprogram covers a broad technology portfolio that includes alternative fuels (e.g., biofuels, electricity, hydrogen, natural gas, propane) and energy efficient mobility systems. These technologies can strengthen national security through fuel diversity and the use of domestic fuel sources, reduce transportation energy costs for businesses and consumers, and support energy resiliency with affordable alternatives to conventional fuels that may face unusually high demand in emergency situations.

The TI subprogram supports Data and Systems Research activities, which include "living lab" projects—competitively selected, cost-shared projects to validate data, technologies, and systems in the field and inform future research—as well as statutory requirements related to alternative fuels, the annual Fuel Economy Guide, and the State and Alternative Fuel Provider Fleet regulatory program. The subprogram also includes the Advanced Vehicle Competitions activity, which supports science, technology, engineering, and mathematics (STEM) and workforce development interests. The Advanced Vehicle Technology Competitions activity supports a collegiate engineering competition that provides hands-on, real-world experience in advanced vehicle technologies and designs. By engaging university students in advanced technology research and providing specialized training, the Advanced Vehicle Technology Competitions activity helps address workforce development needs for more highly trained engineers and supports national efforts that encourage students to pursue careers in science, technology, engineering, and math.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0*). In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 7-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Objectives	Approach	Accomplish-ments	Collaborations	Overall Impact	Weighted Average
ti091	Solutions for Curbside-Charging Electric Vehicles Planned for Urban Growth	Robert Cox (University of North Carolina at Charlotte)	7-5	3.60	3.50	3.60	3.90	3.60	3.61
ti092	Vehicle Charging Innovations for Multi-Unit Dwellings (VCI-MUD)	Kevin Wood (Center for Sustainable Energy)	7-9	3.38	2.88	2.88	3.38	2.88	3.03
ti093	Electric Vehicle Supply Equipment (EVSE) Innovation: Streetlight Charging in City Right-Of-Way	Miriam Bouallegue (Metropolitan Energy Center)	7-13	3.40	3.10	3.00	3.40	3.00	3.14
ti094	Advanced Transportation Hub Efficiency using Novel Analysis (ATHENA)	Caleb Phillips (NREL)	7-17	3.38	3.50	3.63	3.75	3.63	3.56
ti095	High-Performance Computing (HPC) for O'Hare Hub	Aymeric Rousseau (ANL)	7-21	3.38	3.50	3.38	3.63	3.50	3.44
ti096	Technology Integration to Gain Commercial Efficiency for the Urban Goods Delivery System	Anne Goodchild (University of Washington)	7-25	3.25	3.38	3.13	3.63	3.25	3.26

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Objectives	Approach	Accomplish-ments	Collaborations	Overall Impact	Weighted Average
ti097	Drones, Delivery Robots, Driverless Cars, and Intelligent Curbs for Increasing Energy Productivity of First-/Last-Mile Goods Movement Agreement	Constantine Samaras (Carnegie Mellon University)	7-29	3.13	3.50	3.38	3.25	3.38	3.34
ti098	Transportation Energy Analytics Dashboard (TEAD)	Michael Pack (University of Maryland)	7-33	3.17	3.50	3.33	3.50	3.00	3.32
ti099	Understanding and Improving Energy Efficiency of Regional Mobility Systems by Leveraging System-Level Data	Zhen Qian (Carnegie Mellon University)	7-36	3.00	3.33	3.33	3.33	3.00	3.23
ti100	High-Dimensional, Data-Driven Energy Optimization for Multi-Modal Transit Agencies	Philip Pugliese (Chattanooga Area Regional Transit Authority)	7-40	3.33	3.50	3.33	3.50	3.33	3.38
ti101	Mobility and Energy Improvements Realized through Prediction-Based Vehicle Powertrain Control and Traffic Management	Thomas Bradley (Colorado State University)	7-43	3.33	3.50	3.33	3.50	3.00	3.35
ti102	Advancing Platooning with Advanced Driver-Assistance Systems Control Integration and Assessment	Hoseinali Borhan (Cummins-Peterbilt)	7-46	3.50	3.50	3.33	3.50	3.50	3.43
ti103	Fuel-Efficient Platooning in Mixed Traffic Highway Environments	Jeff Rupp (American Center for Mobility)	7-49	3.33	3.33	3.33	3.50	3.33	3.35
ti104	Using Real-Time Mass Transit in First-/Last-Mile Solution	Andrea Broaddus (Ford)	7-53	3.25	3.25	2.50	2.75	2.75	2.85

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Objectives	Approach	Accomplish-ments	Collaborations	Overall Impact	Weighted Average
Overall Average				3.33	3.37	3.27	3.50	3.25	3.32

Presentation Number: ti091
Presentation Title: Solutions for Curbside-Charging Electric Vehicles Planned for Urban Growth
Principal Investigator: Robert Cox (University of North Carolina at Charlotte)

Presenter

Robert Cox, University of North Carolina at Charlotte

Reviewer Sample Size

A total of five reviewers evaluated this project.

Effective Use of Project Resources

40% of reviewers indicated that resources are being used wisely, 20% of reviewers indicated that resources might be used wisely, 0% of reviewers indicated that resources are not being used wisely, and that 0% of reviewers did not indicate an answer.

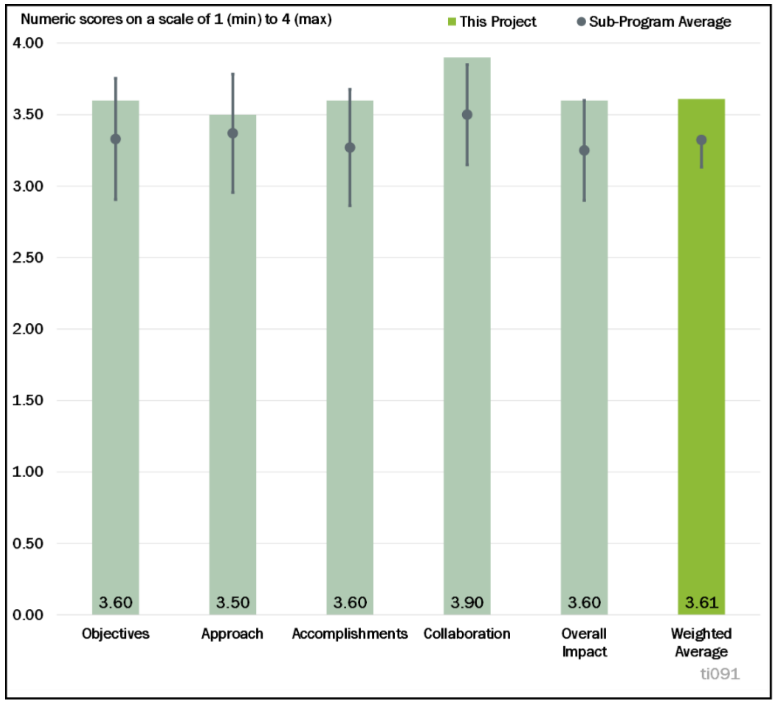

Figure 7-1 - Presentation Number: ti091 Presentation Title: Solutions for Curbside-Charging Electric Vehicles Planned for Urban Growth Principal Investigator: Robert Cox (University of North Carolina at Charlotte)

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

Providing opportunities for charging electric vehicles (EVs) for households and businesses that do not have off-street parking with access to electricity is essential to expanding the market for EVs. This project addresses a promising approach that has the potential to cost effectively enable such charging opportunities, thereby increasing fuel diversity via alternative fuels and increasing energy efficiency via electrification of vehicle travel.

Reviewer 2:

The project supports the Vehicle Technologies Office (VTO) objectives for fuel diversity by supporting a significant expansion of electric vehicle service equipment (EVSE) infrastructure through streetlight retrofits. The prototype includes hardware, software, enclosure, and integration.

In addition, the project team has written a paper that documents the barriers, both policy and technical, to deploying charging EVSE. The paper will ensure findings reach VTO’s broader set of stakeholders.

Reviewer 3:

It appeared to this reviewer that the objective to develop effective streetlight-based EVSE with versatile curbside integration is a strong project objective. There did not appear to be a cost target for developed EVSE units in relationship to other level 2 (L2) charging solutions.

Reviewer 4:

Professor Cox was able to describe succinctly the goals and objectives of the program and provide a clear understanding of the program elements and the status of progress to date.

Reviewer 5:
This reviewer observed that the project team is attempting to deploy an important charging technology that does not have a long track record in the United States.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:
The reviewer observed an excellent team that covers all the bases as well as a thoughtful, technical approach to developing and evaluating new hardware. The project appears to be on time and a detailed description of enabling technology was noted by the reviewer.

Reviewer 2:
The project design effectively addresses all key elements necessary for success: engineering design of appropriate and economical EVSE; siting in collaboration with communities and relevant agencies; laboratory and in situ testing; assessment of technical and economic potential and development of a business model; and commercialization.

Reviewer 3:
Despite the challenges of COVID-19, the project appears to be on schedule and on track. The project partners have been working well together in a coordinated fashion. The approach seems straightforward; the results achieved to date are tangible.

Reviewer 4:
The presentation demonstrated a logical project design, with balanced and well-organized task areas (prototype development, community engagement, and techno-economic analysis). It seems that the project is not really exploring the utility rate implications of streetlight charging. It is not clear to what extent the project will examine potential demand-charge management or EVSE load sharing to reduce charging rates and ensure local grid capacity (in the case that the streetlight EVSE were widely deployed in a given area). Details on the methodology for choosing field demonstration sites were not covered in the presentation. The reviewer commented that the approach may be good, but it was not mentioned.

Reviewer 5:
The project approach is divided into three discrete tasks: prototype development, stakeholder engagement, and techno-economic analysis. The approach offers the opportunity for adjustments to the field test via stakeholder input. One area of uncertainty for the project team to consider is how to ensure the 2021 commercial demonstration in parking lots is representative of other urban cities, some of which may have few parking lots or more parking and access restrictions compared to Charlotte, North Carolina.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:
Progress on using Azure cloud technology to control hardware is impressive. The reviewer observed a strong vision for the project potential, specifically about greater use of light poles.

Reviewer 2:
The reviewer remarked that the project accomplishments (development of a prototype, field deployment, grid testing, and documentation) are excellent. The project team is encouraged to accurately address questions around utility barriers, including zoning and permitting issues. Accomplishments should include clear answers to the key questions identified by the team, both policy and technical. The technical questions provided are excellent and should be answered so a non-technical audience can understand findings.

Reviewer 3:
The enabling technology appears to be working as designed, and the alpha prototype seems ready for field testing.

Reviewer 4:
Although the project is only 45% complete, the behind the fence work appears to have been successfully completed along with the groundwork for community involvement and support. Negotiating agreements appear to have taken longer than expected and required some adaptation, but the project remains on schedule, which appeared to the reviewer to be quite an accomplishment in such challenging times.

Reviewer 5:
The project appears to be well on schedule and on track at 45% complete and 18 months into the project. Substantive technology prototype development milestones have been met, and all field EVSE pilot demonstration sites have been selected. The project is on track to likely deploy five demonstration units, which is five times more than originally planned (the project Statement of Project Objectives [SOPO] called for one demonstration site). Unfortunately, COVID-19 may likely reduce on-campus EVSE use and hinder needed data collection. It would likely make sense to consider extending this project's period of performance to ensure decent data collection.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
The team is collaborating effectively and also coordinating with VTO stakeholders, including Clean Cities.

Reviewer 2:
The project team seems to be working well together in a very well-coordinated manner.

Reviewer 3:
The project team seems to be a diverse, well-rounded team that must be working well together to achieve the progress demonstrated so far.

Reviewer 4:
The project includes a comprehensive team, including a strong technology commercialization partner, an engaged utility, and community outreach and deployment partners. The utility partner, Duke Energy, has control over the EVSE devices, which would help demonstrate demand-charge management and load-sharing opportunities.

Reviewer 5:
With only minor adaptation from the original plan, the researchers have developed all the necessary agreements with local agencies and industry partners.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
The potential for impact on low-cost charging deployment is high.

Reviewer 2:
The project has made good progress developing prototype units, advancing field demonstrations, and identifying issues and best approaches for integrating with existing streetlight types. The applicant is working with Eaton to develop a licensing agreement, and the University of North Carolina at Charlotte (UNCC) to

provide design files for manufacture at a U.S.-based facility. More headway is needed under the project to address community and curbside policy and deployment.

Reviewer 3:
Successfully developing a final design for a feasible and economical streetlight EVSE unit including cellular connectivity is a major accomplishment. Up to this point, all barriers have been overcome. The plan for future field testing and commercialization appears to be appropriate and on schedule. It may be that the researchers could have gained insights from the efforts of others in this type of application but were somewhat constrained by the interests of industry partners. This does not appear to have been an impediment to their work, however.

Reviewer 4:
The impact of using streetlights to address lack of urban EVSE has the potential to change the approach that state and local governments take to build out EVSE, and to reduce the cost of public investment. Findings are encouraging as long as communicated to key audiences.

Reviewer 5:
A successful commercial deployment of this technology will be a significant milestone in bringing curbside charging to communities that do not have it, especially underserved communities.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:
The partnership with the utility is a great move. It is a key factor in ensuring infrastructure is available to a wide swath of society.

Reviewer 2:
This project is a good use of valuable DOE resources. Curbside charging is a critical consideration for charging infrastructure. Successfully achieving this outcome will contribute greatly to the expansion and requirements of community charging.

Reviewer 3:
The project addresses a real barrier to expansion of the EV market. In collaboration with qualified industry partners and relevant government agencies, the researchers have produced what appears to be an appropriate solution. The project plan is well designed, has been successfully accomplished, and is on schedule thus far.

Reviewer 4:
The Department of Energy (DOE) should continue funding streetlight charging development and demonstration projects across different geographies and settings.

Reviewer 5:
Unless the private sector develops a business case for EVSE deployment, DOE should consider future investments in this work.

Presentation Number: ti092
Presentation Title: Vehicle Charging Innovations for Multi-Unit Dwellings (VCI-MUD)
Principal Investigator: Kevin Wood (Center for Sustainable Energy)

Presenter

Kevin Wood, Center for Sustainable Energy

Reviewer Sample Size

A total of four reviewers evaluated this project.

Effective Use of Project Resources

75% of reviewers indicated that resources are being used wisely, 25% of reviewers indicated that resources might be used wisely, 0% of reviewers indicated that resources are not being used wisely, and that 0% of reviewers did not indicate an answer.

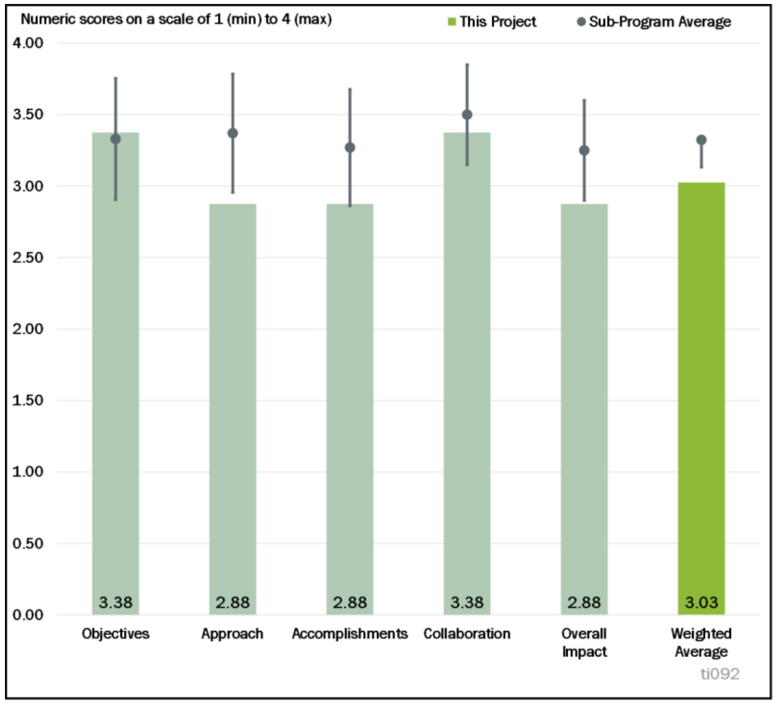

Figure 7-2 - Presentation Number: ti092 Presentation Title: Vehicle Charging Innovations for Multi-Unit Dwellings (VCI-MUD) Principal Investigator: Kevin Wood (Center for Sustainable Energy)

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The project supports VTO objectives for fuel diversity by supporting a significant expansion of EVSE infrastructure through multi-unit dwellings, a key limitation to current EVSE. The study's national scope further supports VTO's broad goals of fuel diversity.

Reviewer 2:

It is great to get an update on a critical gap in charging access. Multi-unit dwellings (MUDs) have always been difficult to access for charging providers and it would be good to see where the technology stands and where opportunities exist.

Reviewer 3:

Facilitating EV charging for residents of MUDs is essential to expanding the EV market, especially in urban areas where EVs can make an important contribution to improving local air quality and where low-cost EV travel can benefit all income groups.

Reviewer 4:

Overall, the project's objective to address the limited availability, high installation costs, and lack of awareness of plug-in electric vehicle (PEV) charging stations for MUD residents is very supportive of EERE's objectives of increasing fuel diversity and increasing transportation system efficiency. Objectives around toolkit development and site demonstrations are less clear from the presentation. The planned toolkit seems ill-defined.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:
The project has an ambitious agenda from baselining to demonstration to evaluation. It is a lot to undertake in a single project, and the reviewer applauded the team for taking this on all at once. The output—the toolkit—could be a very valuable resource for others to build on the efforts of this project.

Reviewer 2:
The survey tool is an effective way to access data on EVSE. Despite data limitations, the approach of survey data and national review of programs via the partners provides a broad set of information. The data limitations— lack of feedback from partners—could have been offset by more survey participants or other means. The demonstration should look to fill gaps in the data collection effort.

Reviewer 3:
The project's general task approach appears reasonably structured, divided into four key discrete task areas. It was not clear to the reviewer how the toolkit would be tested. The tool validation and evaluation approach—working with Idaho National Laboratory (INL), the National Renewable Energy Laboratory (NREL), and Clean Cities (CC) coalitions—does not appear to be fully thought out yet. The project approach was presented at a very high level; details around pilot demonstrations (e.g., criteria or rubric for how demonstration sites have been or will be selected) and what work would go into infrastructure innovation development were not discussed.

Reviewer 4:
The plan calls for first investigating existing MUD EVSE installations, and next identifying innovative solutions developed by technology companies. Not enough information was provided about what the key barriers were (what new insights were gained based on the investigation of existing installations), and how the innovative technologies would be evaluated to determine their ability to overcome the barriers. The reviewer stated that there should be and may be a mechanism to enable feedback from the demonstrations to the technology companies to facilitate product innovation, but this was not described in the presentation. Perhaps this is what was meant by capture stakeholder input on barriers and motivation, but it does not come across as a complete plan for feedback and innovation.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:
The reviewer commented that creation of a toolkit, as described, will be useful to VTO stakeholders and partners. The demonstration project appears to be on track with a number of partners lined up to participate.

Reviewer 2:
So far, the project is on schedule and under budget. However, it seems that MUD infrastructure installations have been more difficult than the project plan anticipated. It would have been appropriate to present an analysis of the problems and barriers found, how the problems and barriers might be addressed by the innovative EVSE to be tested, and what barriers might remain that either technology or policy could address.

Reviewer 3:
The reviewer stated that the team is doing well adjusting to the realities of COVID-19 by doing more webinars. The first year has been a lot of contracting, which is an understandable time sink. It looks like a strong effort to collect information to establish a baseline. The loss of some partners and lack of valuable data from other partners may hinder the value of the results. It seems like the data may not be accurate.

Reviewer 4:
The project has had substantial difficulty identifying additional potential MUD EV charging infrastructure data providers, which has hampered progress. Data collection has been impacted by partners that have dropped out or not participated as anticipated. This may have impacted baseline data results. Only 10% of charger data collected thus far is from MUDs.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
The project has an impressive and appropriate list of collaborating stakeholders, technology companies, and governmental agencies. The reviewer opined that this should help to maximize the impact of the demonstration project.

Reviewer 2:
The project team seems to be working well together with frequent check-ins. A very large number of organizations is involved in this project, and that requires a lot of coordination.

Reviewer 3:
Numerous EVSE evaluation and demonstration site stakeholders are currently identified. The project involves a large number of geographically dispersed CC Coalitions. Some committed project partners had less useful data than expected while others decided not to participate. Ensuring that these partners were fully secured, ideally at the time of project application, would have likely led to a better result.

Reviewer 4:
The team appears to be collaborating effectively. However, it was unclear why some partners chose not to participate in the survey or provide data.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
The creation of a toolkit that includes input from utilities and other stakeholders will be a valuable contribution to the literature on multi-unit EVSE needs. The reviewer indicated that a discussion of business models and associated challenges therein is also important to the project's impact.

Reviewer 2:
Plans for keeping the envisioned toolkit updated beyond the end of the project are not readily clear. Based on current data collection barriers, it is not yet clear how impactful this project might be.

Reviewer 3:
It is unclear how much new information will come from the project at this time. There is still a lot of potential, but it is a little too early to tell. Project team progress to date does not indicate that it will learn a lot of new information.

Reviewer 4:
This could easily have received a higher rating if more information had been presented about the following: what was learned about barriers from the literature review and initial data collection; how to possibly overcome these barriers via the innovative technologies that will be tested; what might inspire innovation to overcome remaining barriers; and what impact that would likely have on stakeholders and government agencies. This is a very important subject, and the reviewer suspected that the researchers were doing more analysis that could inform these points than what the project team shared in its presentation.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

DOE should continue to fund projects seeking to advance MUD charging. It may be most effective however to focus funds on projects that have a tighter scope and more defined objectives, as well as demonstrate well-secured, data-provider partnerships at the time of application.

Reviewer 2:

It is difficult to overstate the importance of expanding the EV market to solve the MUD charging issue. The overwhelming majority of EV owners live in detached housing and do 80%-90% of their charging at home. Those living in MUDs must have the same kind of opportunities if the market for EVs is to fully develop. Overcoming the barriers to MUD charging through information, innovation, and policy changes is key.

Reviewer 3:

The project appears to provide good value to the U.S. DOE. The only risk is a lack of new information that is not already known.

Reviewer 4:

It is not clear if the project will add new information, data, or findings to the topic of EVSE business models or how partnerships may be developed to support infrastructure that fills gaps, including multi-unit dwellings. If the project has new findings, DOE investment could continue.

Presentation Number: ti093
Presentation Title: Electric Vehicle Supply Equipment (EVSE) Innovation: Streetlight Charging in City Right-Of-Way
Principal Investigator: Miriam Bouallegue (Metropolitan Energy Center)

Presenter

Miriam Bouallegue, Metropolitan Energy Center

Reviewer Sample Size

A total of five reviewers evaluated this project.

Effective Use of Project Resources

80% of reviewers indicated that resources are being used wisely, 20% of reviewers indicated that resources might be used wisely, 0% of reviewers indicated that resources are not being used wisely, and that 0% of reviewers did not indicate an answer.

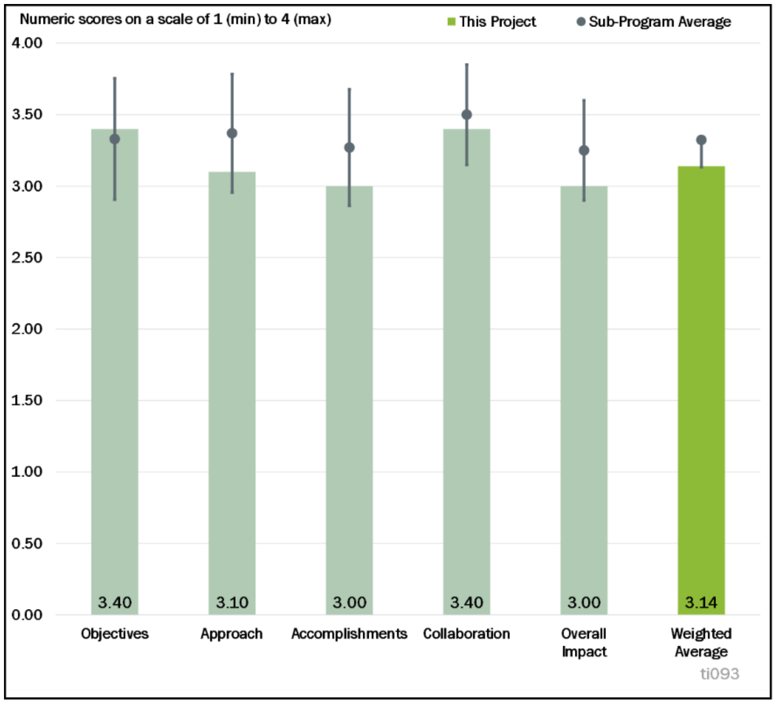

Figure 7-3 - Presentation Number: ti093 Presentation Title: Electric Vehicle Supply Equipment (EVSE) Innovation: Streetlight Charging in City Right-Of-Way Principal Investigator: Miriam Bouallegue (Metropolitan Energy Center)

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The project supports VTO objectives for fuel diversity by supporting a significant expansion of EVSE through the use of streetlight infrastructure. The project also supports VTO goals for fuel diversity, mobility, and equal access to mobility options.

Reviewer 2:

The reviewer stated that streetlight charging in city rights-of-way can clearly provide some electric charging solutions that are not currently available to city dwellers, particularly those without space in their dwellings in which to charge their electric vehicles.

Reviewer 3:

This project aims to demonstrate the feasibility and impact of streetlight EVSE in Kansas City. If this could be accomplished, it would prove that streetlight chargers are a practical solution for providing charging in areas without adequate off-street parking. On-street charging infrastructure is necessary to expand the market for EVs and realize their full potential as efficient, clean, and alternative energy transportation.

Reviewer 4:

The objective to evaluate streetlight-based EVSE infrastructure and study adoption and use data is very supportive of DOE and VTO goals for advancing EVSE availability and increasing fuel diversity. The main thrust of the project is to better understand where to specifically locate streetlight EVSE. Other practical issues, such as how to package such infrastructure, how to integrate it well with the local grid and utility, and how to make it as accessible and easy to use as possible for EV drivers, seem to be missed or deemphasized, perhaps to a fault.

Reviewer 5:
The project has a limited geographic scope (Kansas City only) so it is unclear how replicable it will be.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:
The project has a straightforward approach. The market analysis is a good idea before identifying charging sites.

Reviewer 2:
The plan for deployment and evaluation is appropriate and includes the essential technology, institutional, siting, and evaluation components.

Reviewer 3:
The project's approach—to collect data on site locations and overlay demographics, EV ownership, and environmental conditions—is appropriate. The use of a model that predicts future EV usage patterns helps ensure any investment in new streetlight-based EV charging models will be appropriately targeted.

Reviewer 4:
Budget Period 3 is completely dedicated to putting together the final study and model. This provides an abundant amount of time to conduct technical and market analysis. The underserved model is a good way for identifying areas with high renter-ship, and low EVSE access.

Site selection has been challenging, with the demand model generating 330 potential sites; the project team had to eliminate over 200 of these based on street and parking policy. This suggests the scope of the project effort may have been a bit too large and/or that the modeling methodology requires substantive revision.

Reviewer 5:
While the project approach to supporting the growth of electrification infrastructure options makes sense, the presentation left many questions unanswered concerning the methodology for selecting actual streetlight charging locations.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:
Despite uncertain conditions with the worldwide pandemic, the project has made considerable progress. The development of the predictive model, collection of site data and culling of less than ideal site data are important. The lack of access to city data and input from local government leadership is likely the result of the COVID-19 pandemic. The development of a spreadsheet model on parking and streetlight data seems very valuable; more information would be beneficial to other communities.

Reviewer 2:
Delays in the project are understandable, given the COVID-19 pandemic. The project team is in the process of developing a risk mitigation plan. The predictive model for site identification looks very promising. The reviewer asserted that it would be interesting to know how reusable it is. The underserved model is also a very interesting output from this project.

Reviewer 3:
The project team has made important accomplishments, including evaluating potential sites, analyzing the grid infrastructure to support those sites, and evaluating EVSE and its mounting and connection to the streetlights.

A market-demand model was constructed to inform site selection and evaluation. Unfortunately, the project is somewhat behind schedule with respect to deployment. The COVID-19 pandemic has hindered these efforts. It is reasonable to expect that the pandemic would have a greater impact on demonstration projects than on inside-the-fence projects, such as analytical studies or laboratory projects.

Reviewer 4:
Understandably, the project is behind schedule because of COVID-19. What is still a matter of concern is how the final site selection for deployment will be undertaken. Very little detail was presented on the market-demand model and progress toward the selection of 300 sites that will be required for further evaluation.

Reviewer 5:
The project budget appears to have underspent. The presentation did not describe how the team expects to catch up on its progress.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
The team is a great group of diverse individuals with well-rounded experience. It is well positioned to achieve the project goals. The reviewer was particularly interested in how the team can use the model outputs to help deploy EV charging in underserved communities.

Reviewer 2:
The project team has a well-targeted set of collaborators in industry, government, and research institutions. The team holds regularly scheduled discussions to communicate shared knowledge gained and lessons learned.

Reviewer 3:
The project involves a diverse team, including key municipal, academic, lab, industry, and non-profit partners. All appear to have a substantive role in carrying out the project.

Reviewer 4:
The project team has deep connections and has engaged appropriate partners, including NREL and environmental justice organizations. More detail on the role of key partners would have been helpful. The team is also communicating with another VTO-funded project with related goals for deployment of EVSE at streetlights. DOE EERE's Stakeholder Engagement Guide for Low- and Moderate-Income Communities is a resource available to the project team.

Reviewer 5:
The market-demand model requires the interaction with apartment building owners, restaurants, grocery stores, community centers, parks, churches, shopping malls, and underserved communities. The reviewer's impression was that, based on the presentation, the interactions have not been fully developed and most probably the result of having to address these introductions and discussions virtually instead of in person.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
Valuable progress has been made setting the stage for a successful demonstration. The reviewer hoped that the demonstration can proceed in spite of the pandemic, with appropriate caution. If so, by demonstrating the feasibility and consumer acceptance of streetlight charging, the project will make an important contribution to expanding the market for EVs.

Reviewer 2:
The impact of using streetlights to address lack of urban EVSE has the potential to change how state and local governments address EVSE build-out and reduce the cost of public investment. The project has added significance by focusing on minority and low-income populations with less access to dedicated charging sites at the workplace or at home.

Reviewer 3:
The project will provide modeling methodology from NREL in the final report, but the actual modeling work or model itself will not be publicly shared. The EVSE technology and street pole integration itself were not discussed much in the presentation. It is unclear what the future impact would be of the developed technology.

Reviewer 4:
For the reasons already mentioned, the overall impact of this project has largely not yet been felt. Personal interactions and site visits that can facilitate and accelerate the decision-making process have unfortunately been deferred because of COVID-19, which is certainly not the fault of the grant recipients. In short, because of these external facts over which the grant recipients have no control, the process is taking longer, and the impact is yet to be felt.

Reviewer 5:
It is too early to tell if this project will succeed, given delays associated with COVID-19. The role of NREL in helping with analysis is promising, but it is disappointing that only the process is being shared and not the technology that was being developed.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:
This project has great merit. The success of the project is likely, and the results should be generally deployable across the country. Patience is required to achieve the milestones that are behind schedule. It seemed to the reviewer that consideration should be given to time extensions if this is necessary to complete the project successfully.

Reviewer 2:
DOE should continue funding streetlight charging development and demonstration projects across different geographies and settings.

Reviewer 3:
The reviewer stated that DOE should consider future investments in this work unless the private sector develops a business case for EVSE deployment. This is especially true in low- and moderate-income communities that lack EVSE and whose residents may lack opportunities for charging at home or at the workplace.

Reviewer 4:
Creating convenient and economic opportunities for on-street parking is important to fully developing the market for EVs and extending the opportunity to use clean vehicles with low operating and maintenance costs to underserved communities. The reviewer suggested that a successful demonstration of streetlight EVSE would make a major contribution toward the goals of increasing fuel diversity and energy efficiency.

Reviewer 5:
The reviewer thought that the U.S. DOE should include more requirements around the sharing of technology developed with grant funds (e.g., models).

Presentation Number: ti094
Presentation Title: Advanced Transportation Hub Efficiency using Novel Analysis (ATHENA)
Principal Investigator: Caleb Phillips (National Renewable Energy Laboratory)

Presenter

Caleb Phillips, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Effective Use of Project Resources

100% of reviewers indicated that resources are being used wisely, 0% of reviewers indicated that resources might be used wisely, 0% of reviewers indicated that resources are not being used wisely, and that 0% of reviewers did not indicate an answer.

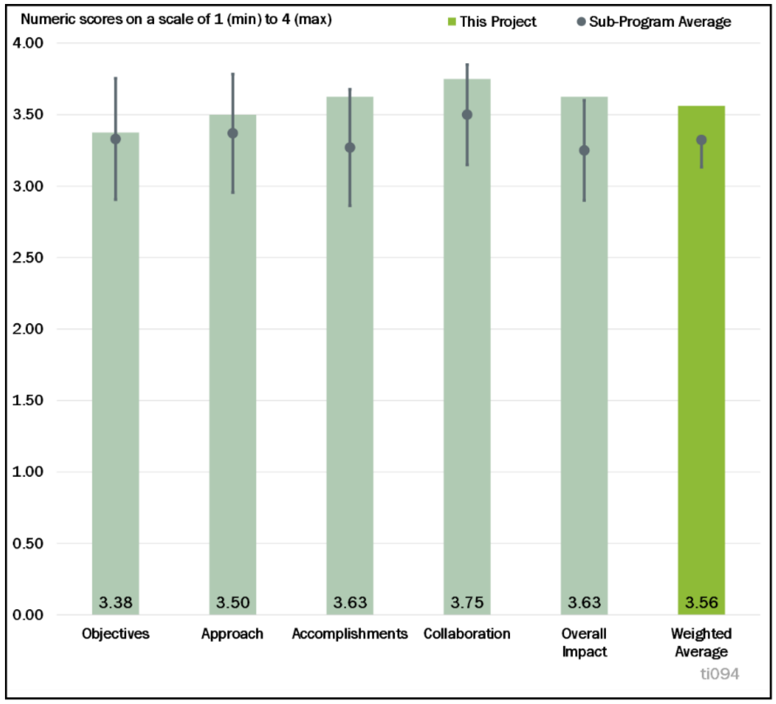

Figure 7-4 - Presentation Number: ti094 Presentation Title: Advanced Transportation Hub Efficiency using Novel Analysis (ATHENA) Principal Investigator: Caleb Phillips (National Renewable Energy Laboratory)

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer remarked that the project objectives were well aligned with VTO goals. The project focused on better understanding advanced mobility technologies at airports, and how advanced technology vehicles and new mobility services impact surface transportation energy use and time efficiencies at the airport.

Reviewer 2:

Project objectives clearly address the need for more efficient airport and travel terminal traffic planning to maximize efficiencies.

Reviewer 3:

The project seems focused on possible electrification, which would move away from gas and diesel but not necessarily diversify to other alternative fuels.

Reviewer 4:

This reviewer cited several items. Firstly, the application of operational models to support near-term needs in planning for shuttle fleet electrification and terminal congestion. Secondly, regarding the project objective of enabling Dallas/Fort Worth (DFW) to demonstrate a 50% reduction in ground transportation energy use for the airport and its connected transportation infrastructure by 2045, the reviewer quoted the following: increasing systemwide affordability, emissions reduction, and improving convenience and efficiency at the connected regional transportation system; and adoption of future technologies. Thirdly, the reviewer noted the next project objective of demonstrating a decoupling between population growth and energy use. Fourthly, the reviewer reported that the process will be replicable to other regional hubs.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:
The reviewer said that the project clearly recognizes the ultimate goal and how to approach identifying the solution(s).

Reviewer 2:
The project approach seems to encompass all of the available resources for information gathering and follows a clear and logical progression toward creating a transportation plan for DFW as well as a blueprint for other transportation hubs to follow.

Reviewer 3:
The approach has the appropriate collaborative partners identified, the collective data identified, and methods for capturing the data.

Reviewer 4:
DFW is working with police to get data on traffic entering and exiting the airport from cameras (not for surveillance purposes, but for tracking the type, number, and occupancy of vehicles and traffic density). This represents a project strength. The project appears to have some notable data gaps; both flight occupancy data (number of passengers on arriving and departing flights) as well as what terminal the flights are arriving into are largely unknown. It is not clear if better airline partnering would aid this (or not). It seemed to the reviewer that circulator fleets from outside the airport (hotel shuttle vans and outside shared van services) are not targeted for data capture. The degree of data capture from individual PEV drivers is not clear either.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:
The project is well ahead of schedule. It has 20 advisors and 3 partners on the project. Data were collected and gaps identified; the Mobility Energy Productivity (MEP) metric, the operational data-driven model, and the bus electrification and route optimization are all complete.

Reviewer 2:
The project is well underway and has collected good data and identified desired data.

Reviewer 3:
Significant progress has been made in identifying information sources and setting up the data-gathering process. The project team is collecting and analyzing huge amounts of data.

Reviewer 4:
The reviewer found that the project accomplishments made to date appear reasonably sufficient.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
The project has identified good and diverse partners and seems to have a structured communication plan between partners.

Reviewer 2:
The reviewer affirmed that the project has over 20 different port advisors and industry advisors supporting the Advanced Transportation Hub Efficiency using Novel Analysis (ATHENA) goals and research objectives.

Reviewer 3:
In addition to the primary research team, the project benefitted from the inclusion of several strong port partners and good industry advisors.

Reviewer 4:
The project team is demonstrating a common commitment to achieve project goals, and individual team members seem to be contributing equally to the project.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
The project has already made substantial contributions by creating a consortium around mobility among numerous ports around the country and by developing and running an operational model of the DFW airport on NREL's high-performance computer (HPC).

Reviewer 2:
This project addresses a crucial need by planning and creating a system for maximizing the traffic efficiency around major transportation hubs, encouraging the use of alternative fuels, and providing a framework for making the system repeatable at other locations.

Reviewer 3:
The project team impact includes creating a consortium around mobility at ports; gathering and identifying key data sets for operational models; creating a metric, MEP, for understanding mobility and energy; developing an operational model of the DFW airport on NREL's (HPC; and evaluating bus electrification and bus route optimization using NREL's HPC.

Reviewer 4:
As the project team identifies metrics to allow comparisons to accurately measure changes, the ability to use the information elsewhere would be very valuable.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:
The reviewer remarked that the budgeted funds have been allocated wisely and effectively and appear to provide a great return for the investment.

Reviewer 2:
The project funds are being used wisely. Airport-focused projects that concentrate on alternative, advanced, automated, and connected transportation are very much worth continued DOE investment.

Reviewer 3:
Identifying how to measure possible fuel efficiency strategies at a transportation hub is very useful if transferable.

Reviewer 4:

DFW is a unique airport with a very inefficient configuration. By building models for other airports and developing standards that can be used in other applications, this work can be utilized in existing locations and as a template to build more efficient airport configurations in the future.

Presentation Number: ti095 Presentation Title: High-Performance Computing (HPC) for O'Hare Hub Principal Investigator: Aymeric Rousseau (Argonne National Laboratory)

Presenter

Joshua Auld, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Effective Use of Project Resources s

75% of reviewers indicated that resources are being used wisely, 25% of reviewers indicated that resources might be used wisely, 0% of reviewers indicated that resources are not being used wisely, and that 0% of reviewers did not indicate an answer.

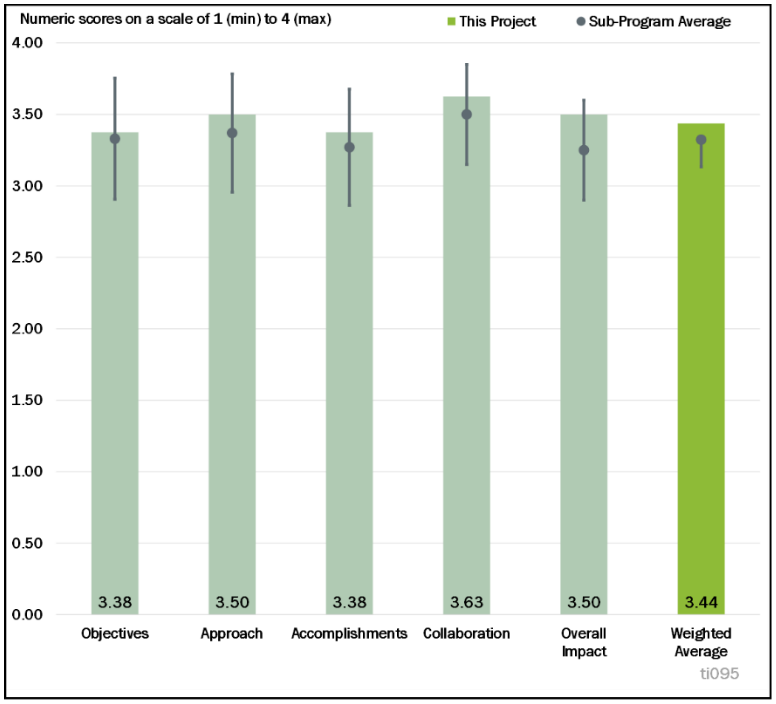

Figure 7-5 - Presentation Number: ti095 Presentation Title: High-Performance Computing (HPC) for O'Hare Hub Principal Investigator: Aymeric Rousseau (Argonne National Laboratory)

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The project, focused on better understanding how advanced mobility technologies and connected transportation impact airport mobility energy productivity, strongly supports VTO priority objectives.

Reviewer 2:

The project objectives are clear, focused, and hit an area of great need. There is a good opportunity to build for the future with traffic efficiency and incorporation of alternative fuel infrastructure in and around transportation hubs.

Reviewer 3:

The reviewer cited the following project objectives: increasing economic growth through commercialization opportunities for vehicle trajectory data; increasing transportation efficiency and reducing time cost to access O'Hare transportation hub to address affordability for business and consumers; and increasing O'Hare traffic reliability through data acquisition and active management to address reliability/resiliency.

Reviewer 4:

This project could decrease overall fuel usage but does not necessarily lead to fuel diversity.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:
The approach is outstanding. System controls are captured, and valuable data is collected. The reviewer noted the project team's subsequent activities: characterize data; edge computing; data management; and short-term forecasting to produce system optimization and continual improvement.

Reviewer 2:
The project creates interesting technology to measure traffic flow and identify real-world fuel usage.

Reviewer 3:
The project is approaching the issue of transportation efficiency from multiple angles and is really leveraging the expertise and experience of Argonne National Laboratory (ANL).

Reviewer 4:
The project takes a fairly comprehensive approach for data collection and analysis, effectively linking disparate data streams for the O'Hare MEP optimization model. O'Hare's use of curbside security cameras is helping better observe and collect data on vehicle occupancy, which is important for estimating accurate MEP. Although, it is not clear how widely this is being done across terminals. The project draws on live traffic data from Illinois Department of Transportation (IDOT) dataset that has been collected for 10 years, which is a strength. Privacy policies may limit data collection, or substantively complicate it.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:
The reviewer commented that the project is progressing well and should collect good data.

Reviewer 2:
The project is about 35% complete and has faced significant barriers, but has accomplished a lot under the circumstances.

Reviewer 3:
The project accomplished a large degree of technical development and data collection work up until March 2020. Due to COVID-19 delays, and subsequent shut down of air travel, the robustness of the project's data collection tasks has been critically affected. The reviewer recommends granting a performance period extension to help ensure better data collection potential.

Reviewer 4:
The project accomplishments include node design prototyping. Prototype 2 development was based on lessons learned from Prototype 1, with advanced resilience and expandability features. This prototype was designed with support for higher quality power over ethernet (POE) cameras and future edge-class central processing units (CPUs) from NVIDIA, Google, and Intel. The project team also has a vehicle classification system to track makes, models, and traffic flows by model. This system provides the flow pattern by vocation and numbers of people per vehicle. According to the reviewer, the project provides valuable information in planning traffic flows.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
The reviewer found the project team to be very strong. The team includes the Chicago Department of Aviation (O'Hare Airport), Chicago Department of Transportation, Chicago Metropolitan Agency for Planning, Arity, the University of Chicago, and Argonne National Laboratory.

Reviewer 2:
The project includes a strong project team.

Reviewer 3:
It seemed to the reviewer that the project team has built a team of collaborators that will be valuable to the project tasks.

Reviewer 4:
Project partners appear to be fully engaged and collaborating effectively. Data collected from IDOT are crucial to the project success.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
When complete, this project will be able to create real, viable solutions to manage the traffic flow and parking around transportation hubs.

Reviewer 2:
The overall market impact is to produce sustainability and replication of developing a traffic and vehicle energy sensing platform that can be used at any airport or traffic hub. This reviewer reported the following impacts: identifying make and model of cars to allow for energy estimation; learning traffic flow characteristics for data input, which will help characterizing traffic conditions and flows at key transportation hubs; allowing for quick expansion to other key transportation hubs and airports; and expanding sensing and coupling with other data sources in a management platform to allow for development of traffic management and optimization capabilities.

Reviewer 3:
The waggle node platform developed and demonstrated under the project could readily be deployed at other airports to collect key airport surface-mode mobility data. The effort is highly replicable.

Reviewer 4:
The project when complete should create methods to analyze traffic patterns and fuel usage, allowing for strategies to increase efficiency. It does not appear to necessarily diversify fuel types.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:
The project is making excellent use of resources, getting input and data from numerous sources, and returning good value for the money spent.

Reviewer 2:
The reviewer said that the DOE resources are appropriate for this project. However, the project has uncovered many areas in which the project team can further optimize traffic flows that will reduce fuel usage and improve time spent in high traffic areas. Replication of the process is very important, and this research should continue.

Reviewer 3:
Funds are being used wisely. Airport projects focused around alternative, advanced, automated, and connected transportation are very much worth continued DOE investment.

Reviewer 4:
It seemed to the reviewer that the project can lead to fuel-use reductions through the identification of traffic and transportation-use patterns and strategies to maximize efficiency. If the project goal is to shift from gas and diesel to alternative fuels, it may not be designed to do so.

Presentation Number: ti096
Presentation Title: Technology Integration to Gain Commercial Efficiency for the Urban Goods Delivery System
Principal Investigator: Anne Goodchild (University of Washington)

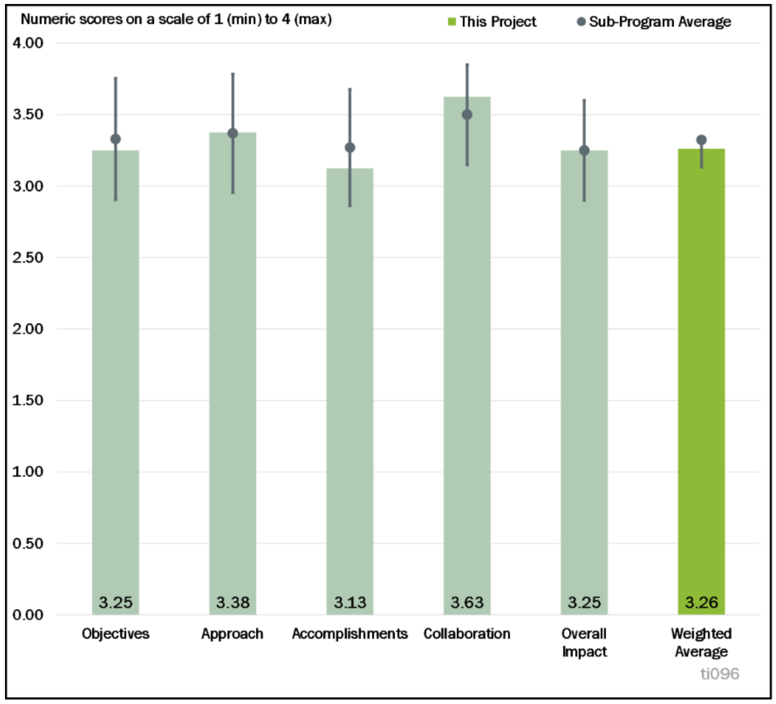

Figure 7-6 - Presentation Number: ti096 Presentation Title: Technology Integration to Gain Commercial Efficiency for the Urban Goods Delivery System Principal Investigator: Anne Goodchild (University of Washington)

Presenter

Anne Goodchild, University of Washington

Reviewer Sample Size

A total of four reviewers evaluated this project.

Effective Use of Project Resources

100% of reviewers indicated that resources are being used wisely, 0% of reviewers indicated that resources might be used wisely, 0% of reviewers indicated that resources are not being used wisely, and that 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The project objective is timely and important. Urban goods delivery is plagued by bottlenecks, inefficient traffic flow and increased fuel consumption. Finding a solution for more efficient delivery of goods will be very beneficial.

Reviewer 2:

The reviewer asserted that the project objectives to reduce parking-seeking behavior and parcel truck dwell time will increase curb and alley space occupancy rates. The project has developed valuable information to reduce fuel usage and emissions as well as improve delivery efficiency.

Reviewer 3:

The project does not necessarily increase fuel diversity, but would contribute to increased transportation efficiency in urban environments.

Reviewer 4:

The project objective and overview slides describe the project's specific objectives and barriers addressed, as well as how the project clearly supports the DOE and VTO objectives of increasing transportation efficiency. The project addresses several of VTO's technology integration goals, such as economic growth and affordability for business and consumers, through activities meant to foster the adoption of energy -efficient logistics initiatives for urban goods delivery. The project objectives appear to be generally effective for the planned scope.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:
The reviewer remarked that this is a really smart way to approach the issue of vehicle idling and wasted fuel.

Reviewer 2:
The project team's approach includes installing lockers and finalizing the plan for placing sensors and lockers on public and private property. The approach also includes selecting a pilot test area and obtaining permissions to execute the plan for the lockers. In addition, the approach calls for issuing a request for proposals (RFPs) and selecting locker vendors; designing and prototyping an app to display real-time parking space availability; and developing models to simulate parking behaviors. These are important areas for project success.

Reviewer 3:
The project approach follows a clear logical path to gather data, identify problems and potential solutions, and work toward achieving goals.

Reviewer 4:
The project approach section provides a generally effective methodology to accomplishing the project objectives and supporting the integration of advanced transportation technologies and practices. The project's approach is to provide real-time information and prediction on commercial vehicle parking occupancy, and the installation and operation of common locker systems. Adequate detail is provided on the approach and milestone slides with regard to the planned tasks and activities.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:
The project team still has a way to go but has identified good data and tactics at this stage of the project.

Reviewer 2:
Considering the recent hurdles, project seems to be on track. Significant research and data gathering have occurred, and the project is moving into more active phases.

Reviewer 3:
The reviewer indicated that generally effective progress has been made toward achieving project goals. The project has completed several key activities: characterized commercial parking behavior through ride-alongs; estimated commercial vehicles' parking-seeking time; designed a prototype app and prediction model for connected vehicle (CV) parking occupancy; and contracted with a locker vendor and identified locations. Despite delays associated with COVID-19, the project team does not anticipate impacts on meeting annual milestones. Furthermore, no concerns have been identified.

Reviewer 4:
This reviewer cited the following accomplishments: estimated commercial vehicles' parking seeking time; designed a prediction model for commercial vehicle parking occupancy and trained on synthetic data; designed and coded a prototype app (currently implemented as a website) to which all drivers will have access; selected and contracted with a locker vendor and Identified locations; and convened stakeholder groups for engagement and information sharing to keep the team informed on the project.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
The project team has put together a very good group of organizations with vested interests and diverse points of view.

Reviewer 2:
The reviewer observed a good team that includes The University of Washington's Urban Freight Lab as project lead; Pacific Northwest National Laboratory (PNNL) as project collaborator; Seattle Department of Transportation, Bellevue Department of Transportation, King County Metro Transit Department, Sound Transit, CBRE, Kroger and Puget Sound Clean Air Agency as cost-share partners; Parcel Pending as locker vendor; and United Parcel Service (UPS), United States Postal Service (USPS), PepsiCo, Building Owners and Managers Association King County (BOMA) as other contributing partners.

Reviewer 3:
This effective project team of academia, a National Laboratory, public agencies, and private industry has assembled to carry out the project and has provided an excellent mix of expertise among team members. Collaboration and communication among the project partners appear to be appropriate for the scope.

Reviewer 4:
Project partners are fully engaged and actively participating, with good communication flow and strong leadership.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
The reviewer remarked that the project has good potential to contribute to increasing transportation efficiency by building knowledge of impacts of insufficient commercial parking, as well as increasing support for urban freight activities from public sector agencies. The finished deployment and evaluation of the package lockers should provide transportation practitioners with a potential solution to the increasing vehicle miles traveled (VMT) and congestion associated with urban package and goods delivery.

Reviewer 2:
It seems to the reviewer that the project addresses a crucial issue facing the transportation industry and will provide much needed solutions for maximizing efficiency in the future.

Reviewer 3:
The project has engaged with independent technology and infrastructure companies to procure and implement solutions. These businesses have economic models that ensure sustaining solutions and implementation in other cities. The reviewer noted that this will improve delivery efficiency and reduce fuel usage and emissions.

Reviewer 4:
The project still has a way to go but shows excellent potential for addressing a serious urban concern. While the project may not advance fuel diversity, it would contribute to efficiency.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:
The reviewer remarked that the project is well managed, appears to be getting good return for the investment, and is leveraging value from project partners.

Reviewer 2:
DOE resources are appropriate for this project, according to the reviewer.

Reviewer 3:
The project has a good cost-share design and seems reasonable, given its potential.

Reviewer 4:
The use of DOE funding to identify activities that foster the adoption of energy-efficient logistics is a critical strategy and activity to increase transportation system efficiency. Projects that serve as “living labs” are important to test new ideas, collect data, and inform research on energy-efficient transportation technologies and systems.

Presentation Number: ti097
Presentation Title: Drones, Delivery Robots, Driverless Cars, and Intelligent Curbs for Increasing Energy Productivity of First-/Last-Mile Goods Movement Agreement
Principal Investigator: Constantine Samaras (Carnegie Mellon University)

Presenter

Constantine Samaras, Carnegie Mellon University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Effective Use of Project Resources

100% of reviewers indicated that resources are being used wisely, 0% of reviewers indicated that resources might be used wisely, 0% of reviewers indicated that resources are not being used wisely, and that 0% of reviewers did not indicate an answer.

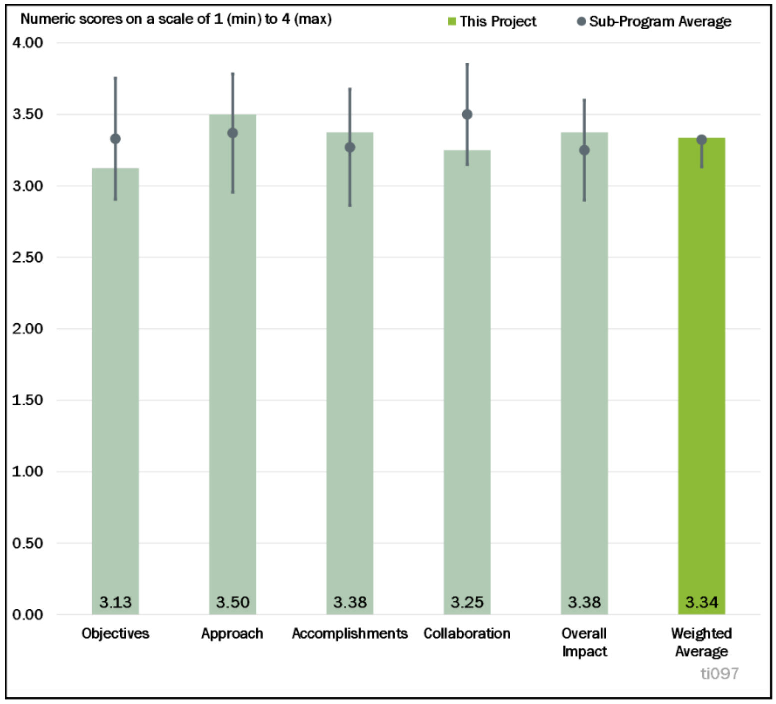

Figure 7-7 - Presentation Number: ti097 Presentation Title: Drones, Delivery Robots, Driverless Cars, and Intelligent Curbs for Increasing Energy Productivity of First-/Last-Mile Goods Movement Agreement Principal Investigator: Constantine Samaras (Carnegie Mellon University)

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The project objective and overview slides describe the project's specific objectives and barriers addressed, as well as how the project supports the DOE and VTO objectives of increasing transportation efficiency. The project addresses several of VTO's technology integration goals, such as national/energy security, economic growth, affordability for business, and reliability/resiliency, through the piloting of goods delivery using drones, ground delivery robots, and automated vehicles. The project objectives appear to be generally effective for the planned scope.

Reviewer 2:

The project objectives are to use empirical testing, life cycle assessment, and systems analysis to research and demonstrate an improvement of at least 20%, compared to a baseline network, in energy productivity of goods delivery using drones, ground delivery robots, and automated vehicles. The project team also plans to develop proof-of-concept testing, a model, and simulation for a smart curb space as an intelligently managed urban delivery zone, with a goal of demonstrating at least an additional 10% improvement in energy productivity.

Reviewer 3:

The reviewer indicated that this project could enhance efficiency but may or may not significantly increase fuel diversity.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:
The reviewer commented that the project approach is well conceived and follows a logical progression to identify and test solutions.

Reviewer 2:
The reviewer reported that the project approach includes the following: designing an experimental protocol for air and ground drone testing; empirically measuring the energy use of air and ground drones; constructing a model of drone and vehicle efficiency, including simulating energy use of a range of driverless delivery vehicles. The approach also includes collecting traffic and delivery data for the test site. Specifically, collecting existing traffic data and validating existing commercial vehicles arrivals data at test site data using sensors, cameras, and existing data sets, and initiating network model development. It appeared to the reviewer that this is a sound approach to meet the project goals.

Reviewer 3:
The project approach section provides a satisfactory methodology to accomplishing the project objectives and supporting the integration of advanced transportation technologies and practices. The approach is divided by project periods, each containing relevant hypotheses and associated tasks. Good detail is provided on the approach and milestone slides with regard to the planned tasks and activities and progress to date.

Reviewer 4:
The project is about integrating multiple methods and modes to increase the efficiency of the first- and last-mile/kilometer delivery. The reviewer remarked that this is very interesting.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:
The reviewer has articulated that good progress has been made toward achieving project goals. The presentation highlighted progress related to drone package delivery and driverless delivery robots. The work associated with smart curb space is on track to finish in budget period 3. No significant concerns have been identified.

Reviewer 2:
The project is reporting good progress, with all of the baseline tasks completed and next steps well underway.

Reviewer 3:
The team seems to be well on its way to identifying potential fuel savings, which are complicated by a lack of existing real-world data.

Reviewer 4:
Regarding project accomplishments, the reviewer reported that the project team recorded testing environment conditions of wind speed, temperature, and other factors. On-board sensors recorded voltage and current, GPS location, speed, wind speed, and drone movement characteristics for each flight, which enabled the team to estimate the energy used for each flight at a high resolution. Another accomplishment cited by this reviewer is that the team designed and executed an experimental protocol to empirically measure the energy use of ground delivery robots carrying a range of payloads through various campaigns. The team also estimated the theoretical propulsion energy use of an electric, rubber-tired delivery vehicles of various masses and assessed the energy tradeoffs between vehicle, battery, and payload mass across a range of existing and potential battery

specific energy values. Furthermore, the team has completed more than 200 package drone test flights and completed more than 100 driverless delivery robot test campaigns.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
The reviewer affirmed that the team was very strong, and all members are making contributions to the project goals. The project team includes Carnegie Mellon University, Pittsburgh Region Clean Cities (PRCC), Amazon, and the City of Pittsburgh.

Reviewer 2:
The team has a strong structure with a diversity of talent and experience. The project team's communication is strong and consistent, and partners are well informed and involved in the process.

Reviewer 3:
An effective project team, assembled to carry out this project with private industry and public partners involved, provides an appropriate mix of expertise among team members. However, the reviewer asserted that the unclear role of Amazon and Pittsburgh Clean Cities in this project was a minor weakness.

Reviewer 4:
It appeared to the reviewer that there were fairly limited partners, but the project is advancing so communication and coordination must be acceptable.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
The potential for cost savings and overall efficiency improvements in this area are significant. This project should provide valuable information to build on as this type of goods movement infrastructure continues to evolve.

Reviewer 2:
The project has good potential to contribute to increasing transportation efficiency through the piloting of goods delivery using drones, ground delivery robots, and automated vehicles. The project has identified several different potential strategies to increase energy productivity of first- and last-mile goods movement, which if proven successful may be utilized and integrated into target markets.

Reviewer 3:
The reviewer said that the current contribution to efficiency and fuel diversity may be limited as the research is still in process, but the potential is significant. Presumably, some of these delivery methods will be electric powered, replacing traditional gas- and diesel-powered vehicles for the first and last mile.

Reviewer 4:
The project team's overall impact was the development of empirical energy-use data generated for package delivery drones and driverless delivery robots. The reviewer stated that this replicable drone energy-use model development can be used in many applications to reduce energy and emissions for package delivery.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:
DOE resources were properly used to develop publicly available, real-world data on drone energy use, which are extremely limited, and the team generated vehicle energy-use data and delivered it to DOE.

Reviewer 2:
The reviewed remarked that this is an area of intense interest to all in the pickup and delivery space. Accomplishments in this area can have significant effects.

Reviewer 3:
The project team has accomplished a lot already and should deliver great value for the investment moving forward.

Reviewer 4:
The use of DOE funding to identify activities that foster the adoption of energy-efficient logistics is a critical strategy and activity to increase transportation system efficiency. Projects that serve as “living labs” are important to test new ideas, collect data, and inform research on energy-efficient transportation technologies and systems.

Presentation Number: ti098
Presentation Title: Transportation Energy Analytics Dashboard (TEAD)
Principal Investigator: Michael Pack (University of Maryland)

Presenter

Mark Franz, University of Maryland

Reviewer Sample Size

A total of three reviewers evaluated this project.

Effective Use of Project Resources

67% of reviewers indicated that resources are being used wisely, 33% of reviewers indicated that resources might be used wisely, 0% of reviewers indicated that resources are not being used wisely, and that 0% of reviewers did not indicate an answer.

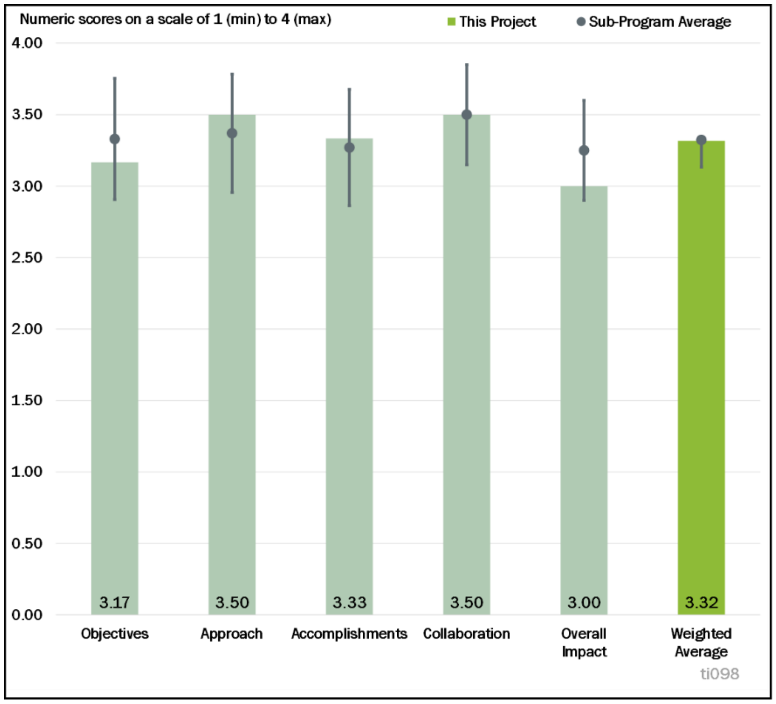

Figure 7-8 - Presentation Number: ti098 Presentation Title: Transportation Energy Analytics Dashboard (TEAD) Principal Investigator: Michael Pack (University of Maryland)

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The project has the potential to allow users to match vehicle, route, etc., to maximize efficiency and emissions reductions. The reviewers remarked this is critically valuable.

Reviewer 2:

The project objective and overview slides describe the project's specific objectives and barriers addressed, as well as how the project supports the DOE- VTO objectives of increasing transportation efficiency. The project addresses several of VTO's technology integration goals, such as national/energy security, economic growth, and affordability for business and consumers, through the development and validation of energy and emissions estimation, as well as on-line analysis tools and real-world use case studies. The project objectives appear to be generally effective for the planned scope.

Reviewer 3:

The reviewer asserted that the researchers did not articulate how this project would lead to increased fuel diversity by use of alternative fuels and increase energy efficiency. The connection appears to be through improving the alignment of goals among safety, congestion, energy use, and emissions. The project team should provide a more explicit connection from the alignment of goals to alternative fuel use and energy efficiency. It seems likely that the tools developed will provide some new insights about traffic and travel behavior and energy use and emissions. Although there seemed to be interest on the part of planners on the stakeholder engagement team, the researchers did not clearly explain how the information generated would be useful to DOE VTO or how stakeholders planned to use the tools to change how they planned and managed transportation systems. This information would be very helpful for evaluating the degree to which the project objectives will support the goals of DOE VTO. For example, perhaps the stakeholders plan to use this modeling framework to plan and/or certify compliance with air-quality standards.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:
The project relies on integrated data collection and analysis. Once complete, it would provide users decision-making data not currently available.

Reviewer 2:
The researchers have a well thought out design for their data acquisition, processing, and prediction/estimation system. The project has a strong team of researchers, system developers, and stakeholders. The project team has chosen appropriate and state of the art data sources and component models (e.g., Motor Vehicle Emissions Simulator [MOVES] and Automotive Deployment Options Projection Tool [ADOPT]) to integrate into their system. Transferability to other states and metropolitan areas is an issue that the reviewer would like to have seen addressed because it will strongly affect the ultimate impact of the project.

Reviewer 3:
The project approach section provides a satisfactory methodology to accomplishing the project objectives and supporting the integration of advanced transportation technologies and practices. The approach is divided by project objectives, each containing associated tasks. Good detail is provided on the approach and milestone slides with regard to the planned tasks, activities, and progress to date.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:
The reviewer indicated that good progress has been made toward achieving project goals. The presentation included nine slides describing the various accomplishments to date. The majority of the tool development, as well as the Transportation Energy Analytics Dashboard (TEAD) interface, has been completed. The work associated with demonstrating the user cases and final deliverables are on track to finish on time. No significant concerns have been identified.

Reviewer 2:
The project appears to be progressing at a good pace and making potentially meaningful strides forward.

Reviewer 3:
The research team has clearly accomplished a great deal with respect to development of the system. The slides state that the project is 60% complete, which is roughly two-thirds of the way along the timeline. However, only 10 of 24 tasks appear to have been completed. Of course, the remaining tasks may well take less time than the earlier ones. The amount and quality of software developed is impressive. The reviewer would like to have seen evidence of stakeholder input, feedback, and their effects on design. This needs to start early in the design process and be sustained throughout. The reviewer was sure this occurred to some extent but would like to have heard about how the process worked and enhanced the usefulness to the stakeholders.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
The selection of partners was good for the project as well as the locations chosen for validation.

Reviewer 2:
The reviewer would have given a higher mark on this if the extent and impact of collaboration with stakeholders had been more fully demonstrated. The collaboration among the methodological and design teams appears to have been excellent. The teams are strong, as mentioned above; the product developed thus far is impressive and appears to have been appropriately validated.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
The reviewer affirmed that the project has good potential to contribute to increasing transportation efficiency by quantifying the benefits of system-level strategies to improve mobility and energy efficiency. However, until the development and launching of the TEAD online tool has been completed and used by the pilots in Columbus and Washington, D.C., it is difficult to evaluate the effectiveness of this research at this time.

Reviewer 2:
It is a little difficult to say how much of the project's current achievements would be useable and valuable today, but the potential is quite significant. If a data dashboard could be created allowing users to look at their routes and identify the optimal times, routes, and vehicle types (and fuels?), it would be an enormous accomplishment.

Reviewer 3:
On this subject, the reviewer was not sure what to say. The reviewer did not think enough of the right kind of information was presented to make a well-informed evaluation. The reviewer was willing to give the researchers the benefit of the doubt, but suspected a higher score would have been given if the team had provided more information on this criterion.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:
Yes, this is a good use of DOE funds. Dashboards that can help users make efficient decisions is a "holy grail" for many vehicle fleets.

Reviewer 2:
The reviewer said that it is important that DOE VTO have data and tools for analysis and evaluation of current and future energy use in transportation. Especially with DOE's focus on transportation system efficiency, tools such as this one could fulfill an important need for DOE and for state and metropolitan agencies.

Reviewer 3:
The use of DOE funding to identify activities that foster the adoption of energy-efficient mobility solutions is an important strategy/activity to increase transportation system efficiency. That being said, it was difficult for this reviewer to understand the project benefits and how they would be used by transportation practitioners.

Presentation Number: ti099
Presentation Title: Understanding and Improving Energy Efficiency of Regional Mobility Systems by Leveraging System-Level Data
Principal Investigator: Zhen Qian (Carnegie Mellon University)

Presenter

Zhen Qian, Carnegie Mellon University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Effective Use of Project Resources

67% of reviewers indicated that resources are being used wisely, 33% of reviewers indicated that resources might be used wisely, 0% of reviewers indicated that resources are not being used wisely, and that 0% of reviewers did not indicate an answer.

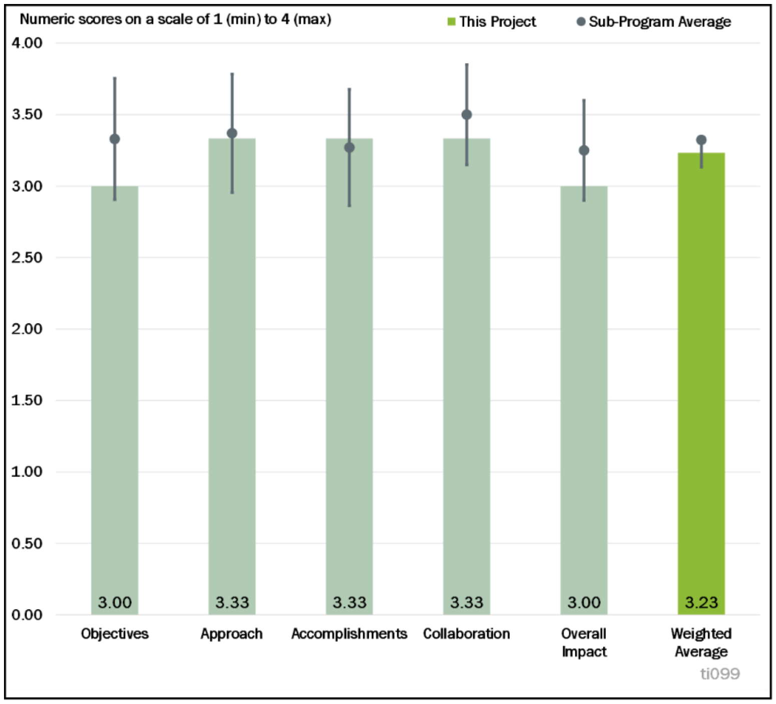

Figure 7-9 - Presentation Number: ti099 Presentation Title: Understanding and Improving Energy Efficiency of Regional Mobility Systems by Leveraging System-Level Data Principal Investigator: Zhen Qian (Carnegie Mellon University)

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The project should result in opportunities to increase transportation efficiencies. The results could increase the justification for electric vehicles and infrastructure.

Reviewer 2:

The project objective and overview slides describe the project's specific objectives and barriers addressed, as well as how the project supports the DOE and VTO objectives of increasing transportation efficiency. The project addresses several of VTO's technology integration goals, such as national/energy security, economic growth, affordability for business, and reliability and resiliency, by quantifying the benefits of system-level strategies to improve mobility and energy efficiency, in Philadelphia and Pittsburgh regions. The project objectives appear to be generally effective for the planned scope.

Reviewer 3:

This project is developing a data and modeling system for estimating and predicting the impacts of various kinds of policies and technologies on energy efficiency and mobility. Like other research and development (R&D) projects of its kind, it would benefit from more precise identification of the kinds of strategies it is designed to evaluate; validation of its methods for the intended analyses; and the kinds and magnitude of effects expected. Clearly, this kind of tool can be useful for VTO for analysis purposes (understanding the magnitudes of energy uses for various types of travel by different types of vehicles in different geographical locations), but the lack of clarity about the questions to be answered and how they will be answered means the reviewer must infer answers to those key questions. Will the key question be just traffic and parking management? Ride sharing is mentioned, but the key issue there is behavioral. How will that be addressed, or will it not be addressed?

Another strategy mentioned is to estimate the impacts of replacing conventional internal combustion engines with EVs, but will choice be considered and the provision of charging infrastructure? Additionally, how much better will this model be than existing aggregate stock-turnover type models? Will the questions be about land use? If so, what controls are to be evaluated? Will it be about vehicle choice? Does it have a vehicle choice model? Will it be about transit and transportation network companies? If so, why are transit trips not included?

The reviewer thought that the system will be valuable to VTO and will make considerable progress in the area of modeling vehicle activity at a detailed spatiotemporal level. And that, in itself, will be an important methodological contribution.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:
Based on the results of this project, when complete, there could be additional justifications for creating infrastructure to better integrate electric vehicles into the system and incentivize more efficient travel patterns.

Reviewer 2:
The project approach section provides a generally effective methodology to accomplishing the project objectives and supporting the integration of advanced transportation technologies and practices. Adequate detail is provided on the approach and milestone slides with regard to the planned tasks and activities and progress to date. The inclusion of two geographically and varied urban environments and cities should help to support the adoption in other locations across the country, if the project approach is successful.

Reviewer 3:
Developing transportation models from the kinds of data and employing the kinds of methods this project is using is the future of transportation modeling. Given a limitation to vehicle travel, the project design is just what it should be: focused on available, geographically, and temporally detailed data with calibration via machine learning. Transferability of the tool depends critically on data structure and availability, a topic addressed by carefully selecting data from generally available sources and creating a data guide.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:
According to the reviewer, the researchers are progressing toward their goals at a good pace. The work completed so far is of value.

Reviewer 2:
Good progress has been made toward achieving the project goals. With only 40% of the time and budget expended, the project has completed many of the milestones and tasks, such as the development of the data guide and web app, as well as starting the Pittsburgh region case study work. The remaining work of budget period 2 appears to be on track to finish on time. It seems to the reviewer that no significant concerns have been identified.

Reviewer 3:
The system has been completed with apparently quite successful calibration, except for the critical step of implementing the different strategies that will affect energy efficiency and alternative fuel use. Development of the software as an open-source tool is exactly the right concept.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
The reviewer remarked that this looks like a good and collaborative effort with appropriate partners for the locations. The meeting schedule should keep the project team on track.

Reviewer 2:
The reviewer indicated that an effective project team has been assembled to carry out this project, with academia, a National Laboratory, public agencies, and Clean Cities Coalition partners involved, and provides an excellent mix of expertise among team members. Team members are well suited to project work, and their working relationships appear to be appropriate for a project of this scope. However, a minor weakness was the unclear role of Pittsburgh Clean Cities in this project.

Reviewer 3:
The reviewer affirmed that the R&D team is very strong both technically and in terms of subject matter knowledge. On the other hand, the role of "Partners" is not as clearly explained as it should be. The Delaware Valley Regional Planning Commission, for example, has relevant expertise that has probably helped by providing inputs to data choice, system design, and strategy evaluation decisions but this is not explained.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
This project could in the future significantly increase overall transportation efficiency. There is some question as to whether the results alone would necessarily increase fuel diversity.

Reviewer 2:
This rating is based on evaluating the project from the perspective of developing spatially and temporally detailed transportation models that can be transferred from one region to another because they can be readily calibrated using widely available data. At present, the reviewer was less certain of its value for evaluating alternative fuel and energy-efficient technologies and policies.

Reviewer 3:
The project has good potential to contribute to increasing transportation efficiency by quantifying the benefits of system-level strategies to improve mobility and energy efficiency. At this point, the progress to date has not delivered any measurable results; however, once the work in Pittsburgh and Philadelphia has been completed, it will be a more appropriate time to evaluate the effectiveness of this research.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:
This project apparently builds on previous data and model development by the U.S. Department of Transportation (DOT), thereby saving substantial resources.

Reviewer 2:
It appears to the reviewer that helping a community to assess the best ways to address transportation needs and efficiency is always going to be helpful. Based on an individual community's findings, using tools such as this, the community may or may not end up diversifying fuels.

Reviewer 3:

The use of DOE funding to identify activities that foster the adoption of energy efficient mobility solutions is a critical strategy and activity to increase transportation system efficiency. That being said, the benefits of this project and how they would be used by transportation practitioners were difficult to understand.

Presentation Number: ti100
Presentation Title: High-Dimensional, Data-Driven Energy Optimization for Multi-Modal Transit Agencies
Principal Investigator: Philip Pugliese (Chattanooga Area Regional Transit Authority)

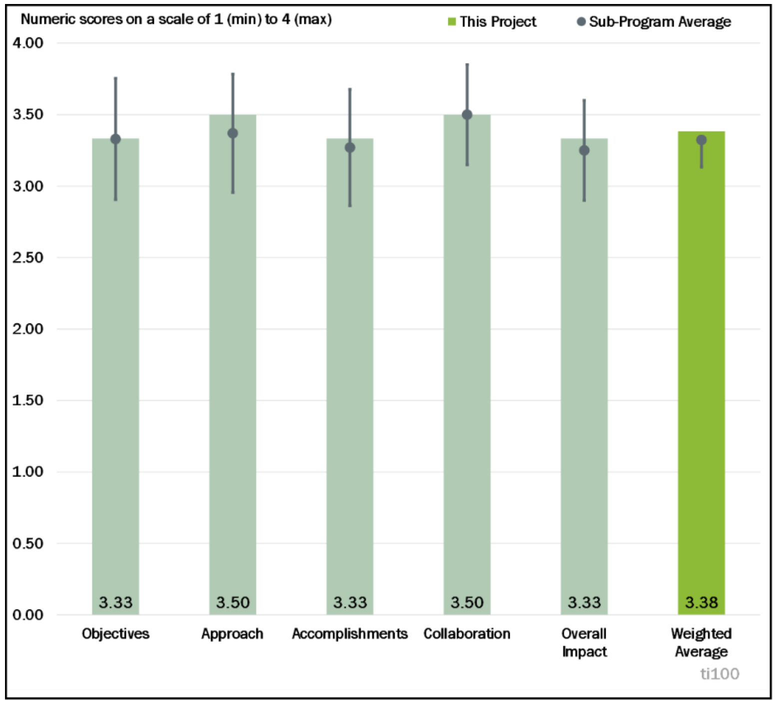

Figure 7-10 - Presentation Number: ti100 Presentation Title: High-Dimensional, Data-Driven Energy Optimization for Multi-Modal Transit Agencies Principal Investigator: Philip Pugliese (Chattanooga Area Regional Transit Authority)

Presenter

Philip Pugliese, Chattanooga Area Regional Transit Authority

Reviewer Sample Size

A total of three reviewers evaluated this project.

Effective Use of Project Resources

100% of reviewers indicated that resources are being used wisely, 0% of reviewers indicated that resources might be used wisely, 0% of reviewers indicated that resources are not being used wisely, and that 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer stated that this project could result in an excellent data-driven decision-making tool for transit agencies. The likely result would be increased efficiencies and some shift to electric vehicles.

Reviewer 2:

Understanding with a high degree of resolution how alternative fuel technologies, such as electric and hydrogen fuel cell buses, will perform in use before purchasing them will be of substantial value to transit agencies. In addition, a tool that can accurately predict how vehicles will perform on specific routes under varying duty cycles will help optimize operations.

Reviewer 3:

The project objective and overview slides describe the project's specific objectives and barriers addressed, as well as how the project supports the DOE-VTO objectives of increasing fuel diversity through the use of alternative fuels. The project addresses several of VTO's technology integration goals, such as national/energy security, economic growth, and affordability for business and consumers, through activities meant to reduce energy consumption of public transit fleets through vehicle optimization. Project objectives appear to be generally effective for the planned scope.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:
The project plan addresses data collection, model development and validation, visualization of outputs, and analysis. Key stakeholders are project team members and have clearly had a strong influence on the project design.

Reviewer 2:
The reviewer stated that this project utilizes advanced data-gathering and analysis technologies to support its goal of energy optimization in a transit system.

Reviewer 3:
The project approach section provides a satisfactory methodology to accomplishing the project objectives and supporting the integration of advanced transportation technologies and practices. The milestone slide provides adequate detail with regard to the planned tasks and progress to date. A weakness is that little detail is provided on the approach slide.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:
Five key milestones have been met and all others are on schedule. The project has already developed useful insights about energy use by electric and diesel buses on different routes, times of day, and weather conditions that will help agencies evaluate the benefits of alternative fuel technologies and optimize their deployment. The finding that optimization of bus operation with the system can produce energy savings of at least 10%, if it holds up across transit properties, will make the system valuable to transit operators.

Reviewer 2:
At this point in the project's budget cycle, the project team has created achievements regarding predictive data that could be of value on their own. Completion of the project will be useful if transferable by location.

Reviewer 3:
The reviewer remarked that good progress has been made toward achieving project goals. The presentation highlighted progress related to energy-analysis comparisons of electric and diesel buses, in terms of energy use per route, as well as minimizing energy use through vehicle assignment and electric charge scheduling. The remaining work of budget period 2 appears to be on track to finish on time. No significant concerns have been identified.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
The reviewer noted that there are strong team partners for the project and its location.

Reviewer 2:
An effective project team provides an excellent mix of expertise among team members, with a transit agency, academia, public agencies, and Clean Cities Coalition partners involved. Team members are well suited for this project work and their working relationships appear to be appropriate for a project of this scope.

Reviewer 3:
The key stakeholders (the Chattanooga Area Regional Transportation Authority, City of Chattanooga, and East Tennessee Clean Fuel Coalition) are well integrated into the project and have clearly had a major positive influence on its design and execution.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
The reviewer asserted that this is one of the best targeted projects evaluated. Transit is a small but important part of the U.S. transportation system and will play a key role in the transition to clean energy in transportation. This project provides transit agencies with a useful tool to help them make decisions about acquisition, deployment, and assignment of electric and fuel cell buses.

Reviewer 2:
The project has good potential to contribute to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency by reducing energy consumption of public transit fleets through vehicle optimization. The ability to optimize vehicle charging, for activities such as in-route charging or as a strategy to minimize demand charges, will be important to ensure that transit agencies will be able to operate these buses in as efficient manner as possible. These results should be shared with the Federal Transit Administration.

Reviewer 3:
The reviewer remarked that, conceptually, this project has significant potential. There is a concern that the data set may not be collected over a long enough period of time to prove out temperature-related issues. However, weather and topography, which can vary quite significantly geographically, would not be material if the dashboard analysis is replicable elsewhere. Allowing an urban transit agency to maximize efficiency and minimize fuel usage could result in major contributions nationwide.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:
The reviewer articulated that the potential to provide transit agencies a method to make data-driven and efficiency-based decisions would result in major economic and fuel savings.

Reviewer 2:
The use of DOE funding to develop models, tools, and other strategies to optimize the deployment of electric transit buses are an appropriate use of federal funds. As more transit fleets are moving toward the deployment of electric transit buses (either through mandates or by choice), it will be critical to incorporate strategies and approaches that will optimize vehicle routes for these new buses.

Reviewer 3:
Key stakeholders are not only providing financial resources but also invaluable expertise that has helped design and guide the project.

Presentation Number: ti101
Presentation Title: Mobility and Energy Improvements Realized through Prediction-Based Vehicle Powertrain Control and Traffic Management
Principal Investigator: Thomas Bradley (Colorado State University)

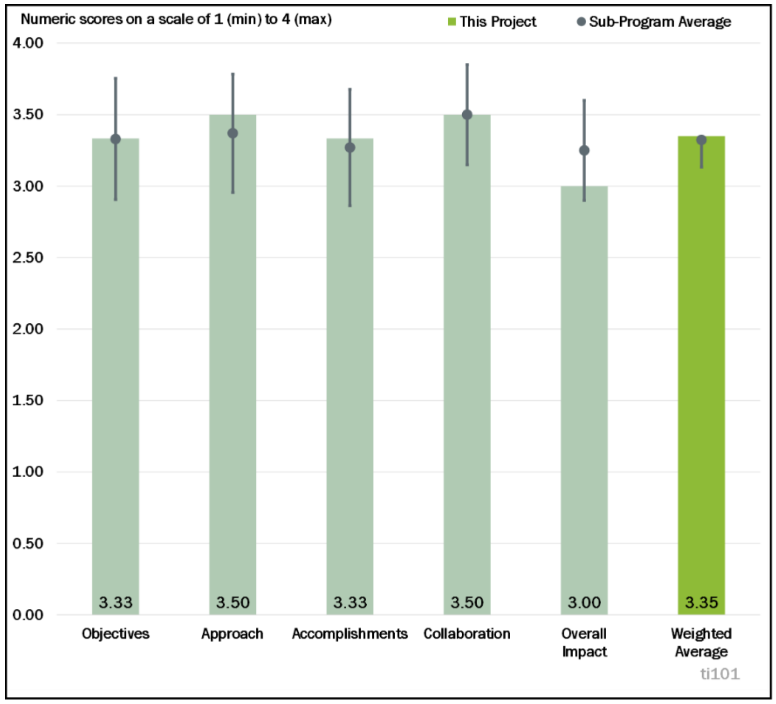

Figure 7-11 - Presentation Number: ti101 Presentation Title: Mobility and Energy Improvements Realized through Prediction-Based Vehicle Powertrain Control and Traffic Management Principal Investigator: Thomas Bradley (Colorado State University)

Presenter

Thomas Bradley, Colorado State University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Effective Use of Project Resources

100% of reviewers indicated that resources are being used wisely, 0% of reviewers indicated that resources might be used wisely, 0% of reviewers indicated that resources are not being used wisely, and that 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The key barrier addressed by this project is the estimation of energy savings to be expected from traffic and vehicle controls enabled by connected automated vehicles (CAVs). This is a key issue for VTO, which has devoted much energy and resources to understanding how advanced mobility systems can increase energy efficiency and support sustainable energy solutions for transportation.

Reviewer 2:

The project objective and overview slides describe the project's specific objectives and barriers addressed, as well as how the project supports the DOE-VTO objectives of increasing transportation efficiency. The project addresses several of VTO's technology integration goals, such as national/energy security, economic growth, and affordability for business, by testing scenarios demonstrating the synergistic benefits of system-level data sharing, infrastructure management, and CAV controls optimization. Project objectives appear to be generally effective for the planned scope.

Reviewer 3:

The reviewer commented that while the project may not necessarily increase fuel diversity, it would potentially provide data allowing for better transportation efficiency and reduced emissions.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:
The analysis of two separate approaches to see if a synergy exists via combined effort is valuable and not easy.

Reviewer 2:
The project approach section provides a generally effective methodology to accomplishing the project objectives and supporting the integration of advanced transportation technologies and practices. Adequate detail is provided on the approach and milestone slides with regard to the planned tasks and activities and progress to date. The inclusion of real-world traffic scenarios, such as traffic congestion along major travel corridors, the interface between bus rapid transit (BRT) and traffic intersections, and through-town Class 8 truck traffic, should provide data and solutions that can be replicated in other areas across the country.

Reviewer 3:
The project design includes all the components necessary to increase DOE's understanding of how CAVs could improve the energy efficiency of urban road transportation though advanced traffic and vehicle controls. The approach is based on answering specific hypotheses about how energy efficiency can be improved by system-wide traffic management and prediction and optimization of vehicle energy use, while at the same time measuring impacts on key performance metrics, such as travel time. Importantly, bus and heavy truck operations are included because, though relatively few in number compared to light- and medium-duty vehicles, they have a disproportionate impact on traffic flow.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:
The project team has made good progress. The achievements thus far are important and will allow for completion of the project.

Reviewer 2:
The reviewer expressed that good progress has been made toward achieving project goals. The project is approximately 66% completed and has completed many of the milestones and tasks, such as data collection and synthesis, microscopic traffic simulation, and model validation. The remaining work of budget period 2 appears to be on track to finish on time. No significant concerns have been identified.

Reviewer 3:
The reviewer indicated that 7 of 10 milestones have been accomplished, and the remaining 3 are on schedule. The main components of the modeling system are complete though integration work remains. This carefully designed and calibrated system demonstrated that, system wide, optimization of traffic controls could improve throughput by 1%-2%. Vehicle-level optimal control for energy use improved fuel economy by 2%-4%. On the one hand, these benefits are relatively minor but, given the size of U.S. transportation energy use, they are important. In addition, it is important to know what the potential for CAV energy-efficiency improvement is at a system-wide scale in order to make decisions about R&D priorities.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
An effective project team has been assembled to provide an excellent mix of expertise among team members; academia, a National Laboratory, public agencies, and Clean Cities Coalition partners are involved. Team

members are well suited for this project work, and their working relationships appear to be appropriate for a project of this scope.

Reviewer 2:
The reviewer remarked that this is a strong team that has clearly worked together effectively to meet milestones on time and within budget, and even at this stage it has created a valid and valuable tool for analysis.

Reviewer 3:
The project seems to have the right partners to accomplish its tasks.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
It is likely that this project will have an important impact on the direction of energy research on the subject of CAVs. To date, the answers are not definitive because the model takes existing infrastructure as a given and changing the roadway infrastructure could have important synergistic effects with CAVs. Still, important progress has been made, and the final results of this project will undoubtedly produce more valuable insights.

Reviewer 2:
The project's accomplishments thus far might not directly contribute to transportation efficiency and fuel diversity but are critical to completion, which could increase transportation efficiency. It does not necessarily appear that the project is designed to significantly increase fuel diversity.

Reviewer 3:
The project has good potential to contribute to increasing transportation efficiency by quantifying the benefits of system-level strategies to improve mobility and energy efficiency. At this point, the progress to date has not delivered any measurable results; however, once the work to reduce travel time and travel time variance in Denver and Fort Collins has been completed, it will be a more appropriate time to evaluate the effectiveness of this research.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:
CAVs as part of an advanced mobility system have been a key focus for VTO for years. This project has produced some, and will produce more, important insights about the potential energy effects of CAVs that will inform future R&D investments.

Reviewer 2:
The use of DOE funding to identify activities that foster the adoption of energy-efficient mobility solutions is a critical strategy and activity to increase transportation system efficiency. Projects that serve as "living labs" are important to test new ideas, collect data, and inform research on energy-efficient transportation technologies and systems.

Reviewer 3:
According to the reviewer, looking at how combining optimized traffic management systems and connected/automated vehicle powertrain control may create transportation efficiencies will be of significant value in the future.

Presentation Number: ti102
Presentation Title: Advancing Platooning with Advanced Driver-Assistance Systems Control Integration and Assessment
Principal Investigator: Hoseinali Borhan (Cummins-Peterbilt)

Presenter

Hoseinali Borhan, Cummins

Reviewer Sample Size

A total of three reviewers evaluated this project.

Effective Use of Project Resources

100% of reviewers indicated that resources are being used wisely, 0% of reviewers indicated that resources might be used wisely, 0% of reviewers indicated that resources are not being used wisely, and that 0% of reviewers did not indicate an answer.

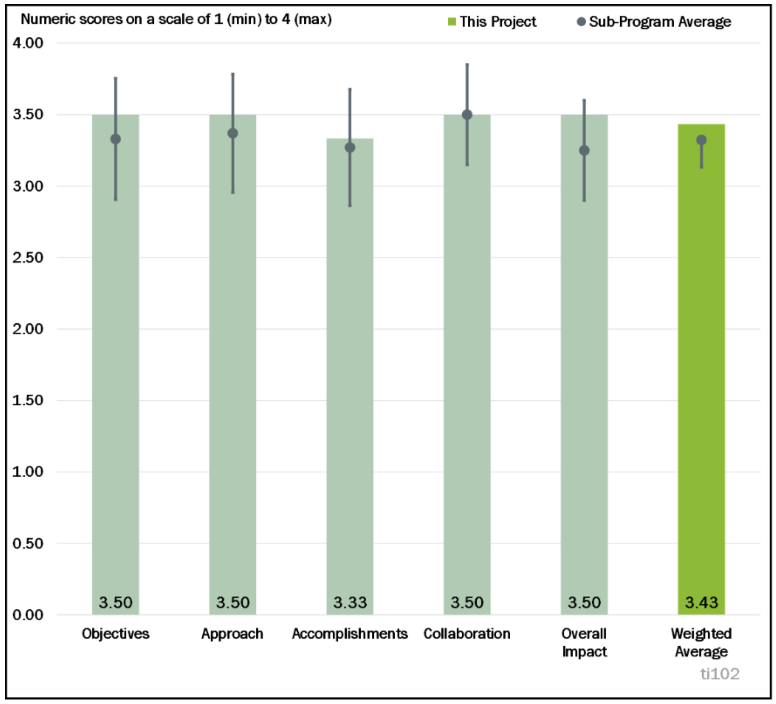

Figure 7-12 - Presentation Number: ti102 Presentation Title: Advancing Platooning with Advanced Driver-Assistance Systems Control Integration and Assessment Principal Investigator: Hoseinali Borhan (Cummins-Peterbilt)

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

This reviewer observed well-defined project objectives, and cited the following: assess the impact of real-world driving conditions on truck platooning fuel saving; assess advanced driver-assistance systems and tire connectivity technology integration; and identify barriers to truck platooning

Reviewer 2:

The project objectives address the critical issue of big truck efficiency with an eye toward preparing for future technology developments.

Reviewer 3:

The project is addressing the increasing transportation efficiency objective. The potential fuel-saving increase from truck platooning is being calculated with real trucks driving in real traffic conditions along routes and driving cycles that represent a national average.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The project approach is excellent. Platooning trucks will be operated on roadways representing the national average with respect to terrain and speed profiles. Data on fuel savings will be collected. The initial tests will be for two-truck platoons followed by three-truck platoon tests. An additional component of the project is investigating the role of tire condition as it relates to tire performance and ultimately to how truck platooning operating parameters may need to change as a function of tire condition. This is critical to maintaining the safety of platoon operations.

One potential area that could be explicitly documented or assessed is the truck driver's reaction, adaptation, etc., to the platooning system. Understanding how the drivers use the system, how they adapt, and their overall impressions on system acceptance are important to capture.

Reviewer 2:
The project approach is very sound in looking for opportunities in technology integration. The project team then plans on testing the technology and finally providing technology solutions for advanced platooning.

Reviewer 3:
The project approach is clear and follows a logical progression with realistic expectations and attainable goals.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:
The accomplishments and progress have been very good. The project team has equipped all three of the test trucks and developed baselines, completed the test factors, selected routes, and have full tire-data connectivity.

Reviewer 2:
The team appears to be making excellent progress on the project. As documented in the presentation, however, there may be some COVID-19 induced delays on the project. The two-truck platooning system has been tested and is ready for testing on real roads. The team has identified two potential routes that map very well to national averages on terrain. There appears to be no major impediments to the real-world tests.

Reviewer 3:
The project is about 30% complete, with much of the legwork and development tasks completed but not much of the actual testing has been done. The reviewer noted that recent disturbances have no doubt played a big role in that, but work is expected to pick up in earnest soon.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
The reviewer commented that a very strong team has been assembled with good communication and data sharing with DOE. The team consists of Cummins, NREL, Clemson University, and Michelin North America.

Reviewer 2:
The team is holding regular bi-weekly meetings and sharing data among themselves and with DOE. All team partners—Cummins, NREL, Clemson University, and Michelin North America—seem to have played important roles already

Reviewer 3:
Partners have clearly defined roles, equal workloads, and responsibilities. The partners seem to be well chosen and represent a well-rounded team.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
The reviewer remarked that this project should have a significant impact on the successful deployment of truck platooning in the future.

Reviewer 2:
The DOE objective for the project is to execute field evaluations of multi-truck platoon proof of concepts that assess both the potential fuel savings and barriers that need to be overcome for platooning to be effective. The reviewer asserted that this objective is being met for this project.

Reviewer 3:
The project has already made contributions to the knowledge base related to truck platooning. The reviewer commented that the project team has done the following: conducted fuel-savings tests of two-truck platoons on a test track; identified potential routes for real-world tests that map to national averages with respect to grade; collected data on tire braking performance with respect to road type, trailer load, brake type, tire brand, and tire wear; and designed a model predictive control) for platooning operations. The real-world road testing and the analysis of three-truck platoons will add to this knowledge base.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:
The reviewer affirmed that DOE resources are properly being used in this project. This project calls for extensive on-road use of platooning and proper research prior to the test period.

Reviewer 2:
The testing done through this project is necessary to the development of truck platooning technology and for maximizing its efficiency. The project represents a wise of use of these funds.

Reviewer 3:
Although there is currently a bit of uncertainly in whether driver-assisted truck platoons (e.g., automation levels 1- 3 with a driver in each truck) will ultimately make business sense, there is new and continued interest in truck platooning with a driver-assisted lead truck and an automated following truck. This line of research supports both the purely driver-assisted truck platooning concepts as well as the “leader-follower” truck platooning concepts. This line of research is also still of interest to DOT, and continued cooperation and collaboration in these areas would be beneficial.

Presentation Number: ti103
Presentation Title: Fuel-Efficient Platooning in Mixed Traffic Highway Environments
Principal Investigator: Jeff Rupp (American Center for Mobility)

Presenter

Jeff Rupp, American Center for Mobility

Reviewer Sample Size

A total of three reviewers evaluated this project.

Effective Use of Project Resources

100% of reviewers indicated that resources are being used wisely, 0% of reviewers indicated that resources might be used wisely, 0% of reviewers indicated that resources are not being used wisely, and that 0% of reviewers did not indicate an answer.

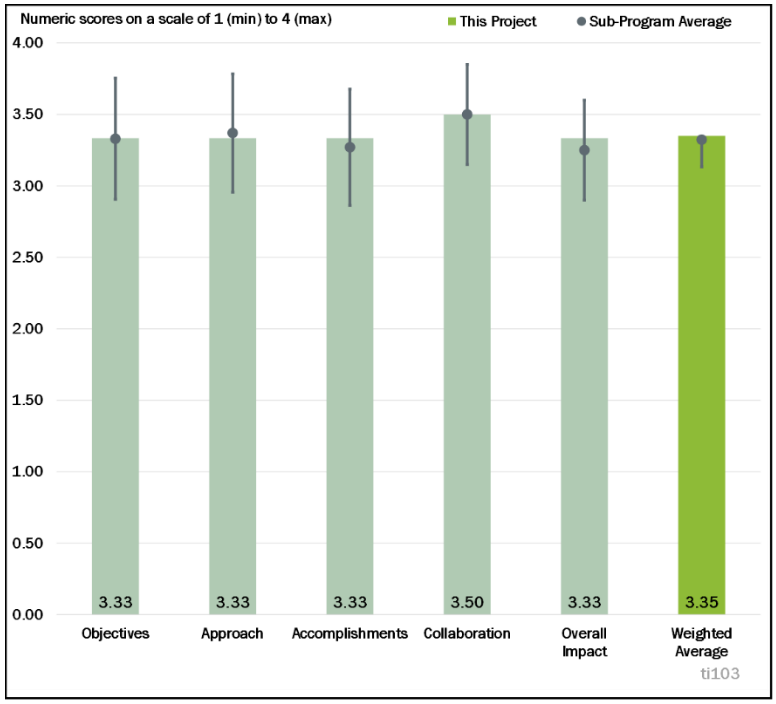

Figure 7-13 - Presentation Number: ti103 Presentation Title: Fuel-Efficient Platooning in Mixed Traffic Highway Environments Principal Investigator: Jeff Rupp (American Center for Mobility)

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
The project objectives support the critical objective of increasing transportation efficiency. Exploring the technologies necessary to make platooning viable is valuable work.

Reviewer 2:
The project objective is to develop vehicle automation for reduced headway that adapts to traffic, road curvature (vertical and lateral), bridges and tunnels, and weather. The team is also going to conduct testing with increasing complexity in four phases—simulation, baseline, advanced, and public (Michigan Department of Transportation [MDOT]-hosted demonstrations.

Reviewer 3:
The project is addressing the increasing transportation efficiency objective by investigating certain aspects of truck platooning systems, which promise to save fuel for trucks on the highway. Of particular interest is that the project is investigating “edge cases,” such as vertical and horizontal road curvature, impact of bridges and tunnels on communications, and impacts of vehicle cut ins. The ability of a truck platooning system to handle these cases may impact both its fuel savings and its user acceptance.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:
The reviewer affirmed that the project approach is sound. The team will test vehicles in varying automated platoon configurations while measuring fuel consumption and then increase the complexity of driving scenarios.

Reviewer 2:
This project has a comprehensive approach to development of systems and testing a variety of trucks in numerous platooning configurations. This should provide valuable building blocks for improving the efficiency of trucking operations in the future.

Reviewer 3:
The approach seems to be good. It incorporates simulation, "simple" test-track testing on a flat oval track, and more advanced test -track testing of a more complex environment, the American Center for Mobility test track. The final component is a "demonstration" on real roads. However, it is unclear what the purpose of the demonstration will be. Will it be for further data collection and analysis of the truck platooning systems or will it truly just be a demonstration of the system on real roads?

The project is testing variations in a number of trucks and types of trucks, which is good. However, it is unclear why a lot of effort is being spent on four-truck platoons. It is unlikely that four-truck platoons will be operating in very many situations, at least for commercial vehicles. The reviewer asked if perhaps the Army has additional objectives. It is also not clear, at least in the presentation, what the plan is for testing the various combinations, such as number of trucks, truck types, and leader-follow positions. Will all combinations be tested or just some subset?

Determining safety margins for different types of weather is an important component of this project. Safety always needs to come first, so investigating if the platoon can still safely operate under different weather conditions is important. If the trucks can operate in platooning mode with increased gaps depending on weather, this allows fuel savings (though reduced) to still occur.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:
The project has shown great progress, with development tasks completed as well as a good portion of the actual testing.

Reviewer 2:
The project has made progress testing a four-truck platoon at 45 miles per hour (mph). This testing showed that even at 45 mph, there were still fuel savings. While larger fuel savings will occur at higher speeds, there may be many instances where trucks need to travel at lower speeds, so if the platoon can be maintained at these lower speeds, fuel savings can still occur. Testing of vehicle-to-vehicle (V2V) communications under road curvatures, bridges and tunnels, and varying weather has also been accomplished. These results could provide important information for any platooning system that has "look ahead" capability to anticipate and adjust to some of these key infrastructure features and road-curvature geometrics along the route. Some progress on the project can be expected to be delayed due to COVID-19.

Reviewer 3:
Project progress and accomplishments include example fuel consumption testing with lap-averaged fuel analysis, controller area network fuel rate, and propagation of disturbances. Additionally, the team has indemnified radio and signal strength requirements as well as simulated the impacts of weather on project results.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
The reviewer stated that there is a very strong team assembled, with adequate communication between members. The team includes the American Center for Mobility; Auburn University; University of Michigan at Dearborn; MDOT; U.S. Army Combat Capability Development Center, Ground Vehicle Systems Center; and NREL.

Reviewer 2:
Each partner brings significant experience and expertise to the project, and the project appears to have effectively leveraged the strengths of each partner.

Reviewer 3:
The team appears to be collaborating very well. Various aspects of the project have been accomplished by different team members, and testing has occurred at two different team member locations.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
Experience and analysis gained from this testing will have a significant impact on the development of safe, effective platooning practices for future implementation as technology allows.

Reviewer 2:
This project will make a particular impact on understanding the "edge cases" related to truck platooning, such as how to operate on severe horizontal and vertical curves, around bridges and tunnels, and under various weather conditions. Some of this type of information has already been produced by this project, and more information will be collected. For the future data collection, it is important to understand what the project intends to collect, given the limited resources and the various combinations of truck type, number of trucks, truck loads, etc., that could potentially be tested.

Reviewer 3:
This reviewer reported that the project achieved reduced fuel consumption during four-truck platooning (45 mph, unloaded, mixed platoon) by 5%-10% for following vehicles and 0%-4% for the leading vehicle. Automation algorithms demonstrated the ability to lengthen headway gap for cut-in traffic. V2V communications have shown resilient to vertical road curvature, bridges, tunnels, and weather.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:
Good use of DOE resources as platooning has a significant pathway to reduce fuel consumption and reduce vehicle emissions.

Reviewer 2:
This project has managed its resources well and represents a good return on funds invested.

Reviewer 3:
Although the reviewer answered "yes" to the question of continued DOE funding, the caveat would be to focus the truck platooning scenarios on more near-term platooning configurations. This project includes studying

four-truck platoons; however, this type of configuration does not seem to have a business case, at least in the nearer term commercial sector. Perhaps the Army has its own interests, though.

Presentation Number: ti104
Presentation Title: Using Real-Time Mass Transit in First-/Last-Mile Solution
Principal Investigator: Andrea Broaddus (Ford)

Presenter

Andrea Broaddus, Ford

Reviewer Sample Size

A total of two reviewers evaluated this project.

Effective Use of Project Resources

100% of reviewers indicated that resources are being used wisely, 0% of reviewers indicated that resources might be used wisely, 0% of reviewers indicated that resources are not being used wisely, and that 0% of reviewers did not indicate an answer.

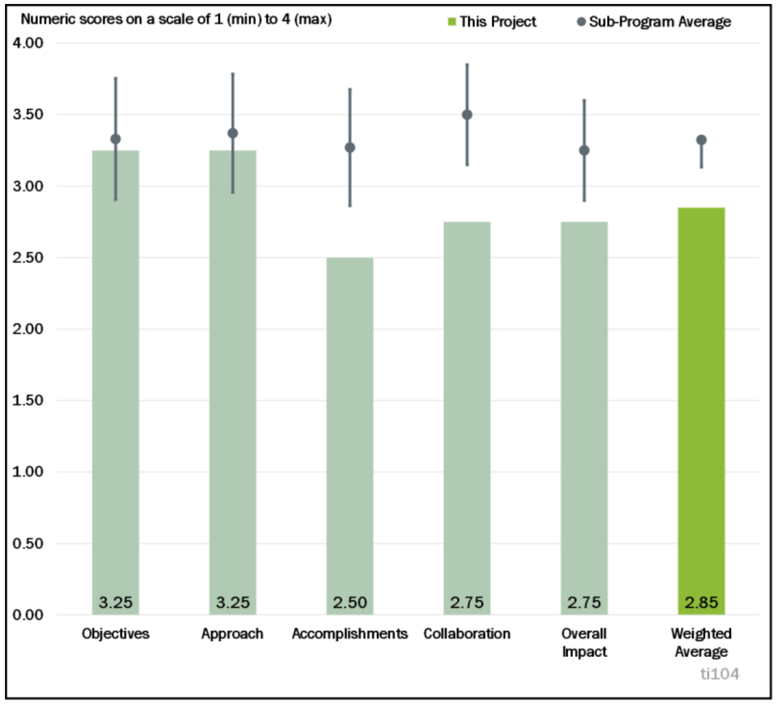

Figure 7-14 - Presentation Number: ti104 Presentation Title: Using Real-Time Mass Transit in First-/Last-Mile Solution Principal Investigator: Andrea Broaddus (Ford)

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

Successful first- and last-mile mobility service for mainline transit could improve energy efficiency, increase the use of mobility powered by electricity, and provide more affordable mobility and accessibility.

Reviewer 2:

The project objective and overview slides describe the project's specific objectives and barriers addressed, as well as how the project supports the DOE-VTO objectives of increasing transportation efficiency. The project addresses several of VTO's technology integration goals, such as national/energy security, economic growth, affordability for business, and reliability and resiliency, by researching, developing, and demonstrating that a first- and last-mile mobility service, integrated with transit agencies' real-time transit and user data, works seamlessly in a simulation environment and a real-world pilot. Project objectives appear to be generally effective for the planned scope.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The project approach section provides a generally effective methodology to accomplishing the project objectives and supporting the integration of advanced transportation technologies and practices. Adequate detail is provided on the approach and milestone slides with regard to the planned tasks and activities and progress to date. The inclusion of two geographically and varied urban environments and cities should help to support the adoption in other locations across the country, if the project approach is successful.

Reviewer 2:
The approach combines initial stated-preference surveys and computer simulations with two real-world pilot projects to understand travelers' actual choices. It finishes with analysis, evaluation, and dissemination of results. The approach has a high probability of producing credible results that will influence investment decisions. Importantly, the pilot projects will include, rail, bus, and BRT services.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:
To date, only 25% of the project is complete after about 50% of the scheduled time has elapsed. The project leaders have faced unexpected challenges in the loss of a transit service provider for the pilot projects and from the COVID-19 pandemic, which has had major negative impacts on mass transit. The shuttered provider has been replaced. However, only the service provider acquisition milestones have been completed. The simulation model development and stated-preference survey tasks are underway and appear to be nearing completion. The project has a year and a half left to go and may still finish on time.

Reviewer 2:
Slow progress has been made toward achieving project goals, due to the need to replace a micro-transit partner Chariot, which went out of business, and delays associated with COVID-19. The project is approximately 25% completed and has only completed 2 of 10 milestones, with 2 in progress. It is not clear if this project can finish without a project end-date extension.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
It appears to the reviewer that the project team is solid and will succeed. However, it is still early, and the pandemic is still having a major impact on mainline transit operations. The situation will have to be monitored, and an extension may be necessary.

Reviewer 2:
The project team appears to provide an appropriate mix of expertise among team members, with a major vehicle original equipment manufacturer, academia, transit agencies, and a micro-transit provider included. Team members are well-suited for this project work and their working relationships appear to be appropriate for a project of this scope.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
The project has good potential to contribute to increasing transportation efficiency by demonstrating that a first- and last-mile mobility service, integrated with transit agencies' real-time transit and user data, can improve mobility and energy efficiency. At this point, the progress to date has not delivered any measurable results; however, once the work associated with the King County and Minneapolis pilot projects has been completed, it will be a more appropriate time to evaluate the effectiveness of this research. Additionally, because only 15 minutes (versus the usual 30 minutes) was allotted for the presentation, the presenter did not go through all of the slides or have an opportunity for Q&A.

Reviewer 2:
The project's contributions to date have been small due to unforeseen delays. However, if successful, the project could play an important role in the future by demonstrating the benefits of integrating line-haul transit with automated (or, less likely, un-automated) first- and last-mile services. This could be a substantial benefit for transit operators as well as current and potential transit riders in urban areas.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:
The use of DOE funding to pilot first- and last-mile micro-transit shuttles and evaluate technology solutions for transit is an important strategy and activity to increase transportation system efficiency. Projects that serve as "living labs" are important to test new ideas, collect data, and inform research on energy-efficient transportation technologies and systems.

Reviewer 2:
Transit is a small but important part of the U.S. transportation system. For many, it is the only viable option for getting to work. Demonstrating positive synergy between main-line transit service and first- and last-mile ride service could increase the importance of transit in the future mobility system in ways that increase energy efficiency, diversify energy sources, and expand the mobility and accessibility options for those needing affordable transportation.

Acronyms and Abbreviations

AFDC	Alternative Fuels Data Center
ANL	Argonne National Laboratory
ATHENA	Advanced Transportation Hub Efficiency using Novel Analysis
BOMA	Building Owners and Managers Association
BRT	Bus rapid transit
CAV	Connected automated vehicle
CC	Clean Cities
CPU	Central processing unit
CV	Connected vehicle
DFW	Dallas-Fort Worth International Airport
DOE	Department of Energy
DOT	U.S. Department of Transportation
EV	Electric vehicle
EVSE	Electric vehicle service equipment
HPC	High-performance computer
IDOT	Illinois Department of Transportation
INL	Idaho National Laboratory
L2	Level 2
MDOT	Michigan Department of Transportation
MEP	Mobility Energy Productivity
mph	Miles per hour
MUD	Multi-unit dwelling
NREL	National Renewable Energy Laboratory
PEV	Plug-in electric vehicle
PNNL	Pacific Northwest National Laboratory
POE	Power over ethernet
POP	unknown acronym
R&D	Research and development

RFP	Request for proposals
SOPO	Statement of Project Objectives
TEAD	Transportation Energy Analysis Dashboard
UNCC	University of North Carolina at Charlotte
UPS	United Parcel Service
USPS	United States Postal Service
V2V	Vehicle to vehicle
VMT	Vehicle-miles traveled
VTO	Vehicle Technologies Office

8. Vehicle Analysis

The Vehicle Technologies Office (VTO) has a comprehensive portfolio of early-stage research to enable industry to accelerate the development and widespread use of a variety of promising sustainable transportation technologies. The research pathways focus on fuel diversification, vehicle efficiency, energy storage, and mobility energy productivity that can improve the overall energy efficiency and efficacy of the transportation or mobility system. VTO leverages the unique capabilities and world-class expertise of the National Laboratory system to develop innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures; and energy efficient mobility systems. VTO is uniquely positioned to address early-stage challenges due to strategic public-private research partnerships with industry (e.g., U.S. DRIVE, 21st Century Truck Partnership) that leverage relevant expertise. These partnerships prevent duplication of effort, focus DOE research on critical R&D barriers, and accelerate progress. VTO focuses on research that industry does not have the technical capability to undertake on its own, usually due to a high degree of scientific or technical uncertainty, or that is too far from market realization to merit industry resources.

The Analysis (VAN) subprogram provides critical information and analyses to prioritize and inform VTO research portfolio planning through technology-, economic-, and interdisciplinary-based analysis, including target-setting and program benefits estimation. The VAN subprogram supports vehicle data, modeling and simulation, and integrated and applied analysis activities using the unique capabilities, analytical tools, and expertise resident in the National Laboratories. Trusted and public data are critical to VTO efforts and are an integral part of transportation and vehicle modeling and simulation. In addition, VAN supports the creation, maintenance, and utilization of vehicle and system models to explore energy impacts of new technologies relevant to the VTO portfolio. The VAN subprogram also supports integrated and applied analyses that bring together useful findings and analysis of the energy impacts of transportation systems through the integration of multiple models including vehicle simulation and energy accounting of the entire transportation system. The result creates holistic views of the transportation system, including the opportunities and benefits that advanced vehicle technologies create by strengthening national security, increasing reliability, and reducing costs for consumers and businesses. Overall, VAN activities explore energy-specific advancements in vehicles and transportation systems to inform VTO's early-stage research and offer analytical direction for potential and future research investments.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0).* In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 81 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
van016	Transportation Data Program	Stacy Davis (ORNL)	8-3	3.67	3.50	3.50	3.11	**3.49**
van017	ANL VTO Analysis Modeling Program	Michael Wang (ANL)	8-10	3.45	3.60	3.50	3.30	**3.51**
van018	Light-Duty Vehicle Choice Modeling and Benefits Analysis	Aaron Brooker (ANL/NREL)	8-17	3.35	3.25	3.20	3.25	**3.27**
van023	Assessing Energy and Cost Impact of Advanced Vehicle Technologies	Aymeric Rousseau (ANL)	8-24	3.45	3.40	3.45	3.30	**3.41**
van032	Tracking the Evolution of Electric Vehicles and New Mobility Technology	Joann Zhou (ANL)	8-31	3.45	3.45	3.10	3.25	**3.38**
van033	Transportation Macroeconomic Accounting Models: VISION and Non-Light Duty Energy and Greenhouse Gas (GHG) Emissions Accounting Tool (NEAT)	Joann Zhou (ANL)	8-38	3.40	3.40	3.30	3.25	**3.37**
Overall Average				**3.46**	**3.43**	**3.34**	**3.25**	**3.40**

Presentation Number: van016
Presentation Title: Transportation Data Program
Principal Investigator: Stacy Davis (Oak Ridge National Laboratory)

Presenter

Stacy Davis, Oak Ridge National Laboratory

Reviewer Sample Size

A total of nine reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 89% of reviewers indicated that the resources were sufficient, 11% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

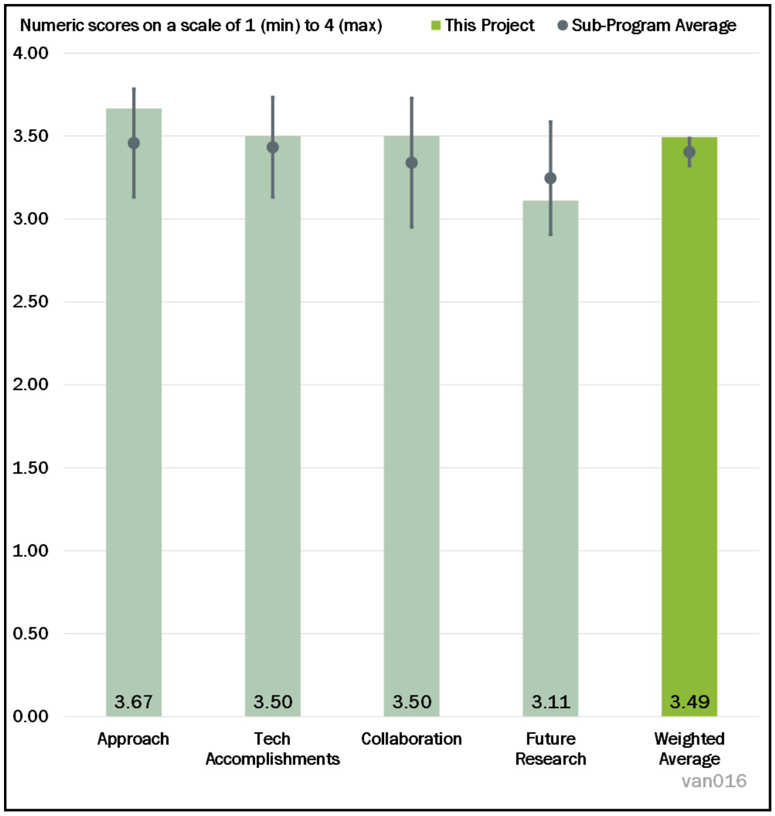

Figure 8-1 - Presentation Number: van016 Presentation Title: Transportation Data Program Principal Investigator: Stacy Davis (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This work clearly addresses a key technical barrier to all work supporting advanced transportation technology research, design, and development (RD&D), availability of, and ease of access to quality transportation data.

The project also specifically lists and addresses barriers from the most recent VTO Multi-Year Program Plan (2011-2015). Its approach addresses Section 2.6 Outreach, Deployment, and Analysis A, B, & C, which discusses the availability of alternative fuel vehicle (AFV) infrastructure, make and model availability, and consumer willingness to purchase an AFV, because it produces and maintains a database of the foundational knowledge required to understand progress on these metrics. It supports Section 3.2 Program Analysis in a similar fashion—by providing the data inputs needed to analyze and model both traditional and advanced vehicle technologies. It provides more targeted outreach for the Vehicle Technologies Office (VTO) through Facts of the Week.

The project approach to overcoming these barriers is well designed and has clear goals—produce the Transportation Energy Data Book (TEDB) annually including interim updates, produce Facts of the Week, and produce special topic reports based on VTO needs. It is entirely feasible, considering it has been completed similarly for multiple decades.

Reviewer 2:

The reviewer observed a thorough approach that reflects the needs of stakeholders and subscribers.

Reviewer 3:
The current approach taken by the investigators is probably most practical and effective given the many challenges associated with collecting and validating data.

Reviewer 4:
The reviewer noted that the Oak Ridge National Laboratory (ORNL) Principal Investigator (PI) continues to successfully address technical barriers and manage the project well.

Reviewer 5:
The reviewer described the project as one of the only transportation-related data resources that compiles information from multiple different sources and is critical for industry and researchers. The reviewer commented the amount of work that goes into this project could be leveraged to gain access to data that is typically inaccessible or of lower quality (e.g., Vehicle Inventory and Use Survey [VIUS] data that was discontinued as of 2002).

Reviewer 6:
Data are the foundation of all research and this project is one of the most critical elements in VTO sponsored research because of its wide-reaching benefits.

Reviewer 7:
TEDB provides several tables and figures to researchers, academics, and investigators, which makes modeling and analysis easier, and combines data from several national agencies and sources. A robust, automatic approach to update these databases would help with more frequent data availability (e.g., each month instead of twice per year). The project is well-established and designed, as demonstrated by the number of citations and the number of people interested in the Fact of the Week (FOTW).

Reviewer 8:
The reviewer mentioned that the technical data collected and compiled is available in multiple formats (e.g., PDF, Excel) and has been widely used to support broader VTO research activities. Some efforts could be made to speed the data collection process through automation and confirmation, and those opportunities should be explored. Reliance on other, private sources of data could be a longer-term threat, both in terms of potential future costs, but especially if the data use becomes more restricted. Longer term strategies could look at partnering with other Federal agencies (Environmental Protection Agency [EPA], National Highway Traffic Safety Administration [NHTSA]), which require manufacturers to report vehicle attribute, sales, and production data as a means of avoiding limitations from privately sourced data (*https://www.epa.gov/automotive-trends/download-automotive-trends-report*).

Reviewer 9:
The reviewer indicated that this program is doing a good and important job, but hoped that there would be some effort to gain more local data going forward. National data is helpful, but state and other sub-national data can vary greatly, especially when it comes to emerging technologies. While this is obviously not feasible for all data, it could be useful for newer, emerging technologies such as electric vehicles (EV) or charging infrastructure.

Given the potential broader impact the data book has with its wide distribution, the reviewer suggested it would be worth spending some time with a data visualization expert to improve most of the charts. Some are terrible, and many are poor. Poor visualizations can be uninformative and potentially misleading (the pie chart on Slide 5, for example). This is not a trivial point because charts are regularly used by the highest decision makers as quick summaries of complex data. It is well worth investing in good design because this entire program is about making data and insights available to modelers and decision makers. Data visualizations translate raw data into insights, and good visualizations can have dramatic impacts on decisions and actions.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer noted the project has met its first three milestones and is on track to meet the remaining two based on the facts below.

Facts of the Week have been published each week since the project's inception.

The draft report on transportation energy including and excluding upstream energy was submitted to VTO.

Edition 38.1 of the TEDB has been published.

Key indicators of TEDB visibility and usage, including over 3,000 Google Scholar citations, suggest the product continues to be valuable for a global range of transportation analysts. Similarly, Facts of the Week continue to maintain a large subscriber list greater than 25,000. New TEDB tables and continued updates to the TEDB website and interface to help users find data more quickly add value.

Reviewer 2:
The reviewer observed data sources are updated consistently and frequently, as are outreach emails through the FOTW program.

Reviewer 3:
The project has consistently provided the data service that it was set to provide, and its performance is excellent based on the number of researchers that are utilizing this database (citations and visitors of the VTO website through the FOTW service).

Reviewer 4:
The reviewer acknowledged transit and shared mobility data will be crucial as the transportation system evolves. The reviewer mentioned the project would be bolstered if TEDB were able to summarize shared mobility data that are typically off limits to the general public.

Reviewer 5:
The reviewer appreciated the drive to expand the TDB to include new areas such as transit and shared mobility. The team is encouraged to continue reaching out and being at the leading edge of providing relevant data on new transportation trends to the transportation industry, DOE, and stakeholders. The reviewer suggested continued interest in emerging light-, medium-, and heavy-duty (HD) technologies, on-highway in particular, as new technology deployment in these areas continues to accelerate.

Reviewer 6:
Progress to date is impressive and the data are very beneficial to other programs and the public. It would be great if the TEDB can include more data of recent years. For example, many of the tables only cover data up to 2017, which have almost three years' lag.

However, the reviewer fully acknowledges that this is very challenging and sometimes beyond the control of the investigators because data sources may simply not be available. The reviewer mentioned that more up-to-date data are highly desirable and encouraged the investigators to include as many as possible.

Reviewer 7:
The PI has made measurable progress against performance indicators by successfully issuing FOTW at the expected cadence and publishing updates to the data book as defined in the project plan. However, benchmarking is needed. Slide 11, in particular ("Page Views, Downloads, Citations"), should be benchmarked against other notable government data compilations (e.g. EIA or DOT data resources).

Additionally, only showing data for the performance period is insufficient to evaluate current performance. The reviewer suggested adding comparison data from at least two to three years prior.

In future evaluations, the reviewer suggested the Slide 16 metric ("As of April 2020, there were greater than 25,100 subscribers to the FOTW email distribution each Monday") should be broken out further to include the email open rate. The reviewer recognized the PI's comment that click through rate is not a helpful metric because sufficient information is included in the email.

Reviewer 8:
The project deliverables are on time and within budget.

Reviewer 9:
The reviewer referenced prior comments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project referred to many other external collaborators and was also acknowledged in many of the other presentations. Tracking the number of projects collaborated on each fiscal year (FY) would probably help to accurately allocate staff resources, as the reviewer is sure these collaborations can vary in the amount of time required to ensure the data is being used correctly.

Reviewer 2:
Project partners include Argonne National Laboratory (ANL) and 6National Renewable Energy Laboratory (NREL), both of which appear to be regularly engaged and an integral part of both FOTW and TEDB processes.

The reviewer highlighted other notable collaborations with private and public entities that provide data for the TEDB (highly valuable network of contacts); other National Laboratories on the total cost of ownership (TCO) team; and other National Laboratories on publishing public-facing summaries of work as FOTW (and to update the TEDB).

Reviewer 3:
It would be useful to consider expanding collaborations beyond National Laboratories by identifying the most frequent data sources cited in the TEDB and engaging them in the data processing process. Coordination across National Laboratories at the moment seems seamless, even though the data connections and exchanges need to be clear.

Reviewer 4:
The project team demonstrated good collaboration with stakeholders and the subscribers to the TDB. The FOTW seems to be an excellent tool for stimulating and facilitating interaction.

Reviewer 5:
The reviewer observed very good collaboration with other DOE laboratories and projects. The data compiled are also widely used by DOE as well as the public.

Reviewer 6:
The ORNL PI coordinates well with key core teams, including the primary audience of the VTO as well as other key laboratories such as NREL (for the Alternative Fuels Data Center [AFDC]) and ANL (for EV market data).

Reviewer 7:
Producing the data book invariably requires seamless collaboration across multiple partners.

Reviewer 8:
The data collection process requires collaboration with public and private entities.

Reviewer 9:
The reviewer indicated no comments.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The reviewer thinks that the existing strategies will probably continue to be effective in the short term, although there are longer term threats to some of the data availability from private entities.

Reviewer 2:
The work is inherently a continuous effort. The TEDB database needs updating and the FOTW needs publishing. Future work entails continuing to complete these tasks, or the TEDB will go out of date and the FOTW will disappear. It might be helpful for the TEDB team to consider what other additional future value could be added to the process. (perhaps automation of data collection for the TEDB).

Reviewer 3:
The reviewer referenced prior comments about extending to state or non-national data.

Reviewer 4:
The proposed future research is tied to the continuation of the TEDB data collection, processing, and distribution. It would be useful to consider the next steps in this effort, including potentially the following:

- Offering the data in other formats, such as shapefiles, structured query language (SQL) relational databases, etc.
- Collecting and providing state level data.
- Automating the process (to the extent that this is possible, recognizing that agencies need to have consistent data handling).
- Formally collecting data feedback from users via surveys and documenting evolving needs.

Reviewer 5:
Future work demonstrates that TDB is responsive to needs of the user community. The reviewer suggests a more proactive approach to expanding the scope of data being gathered and reported. The reviewer recognizes that the mission is driven by the users, but the team may want to consider further stimulating the input. This may be happening anyways and is just not obvious to the reviewer.

Reviewer 6:
Please keep on the good work of maintaining and updating the TEDB and FOTW. The inclusion of transit and shared mobility is a good addition. The reviewer wondered if relevant content related to autonomous vehicles (AVs) and advanced mobility should be included in future publication, if the budget allows.

Reviewer 7:
Proposed future research appears to be the status quo. In the future, please use this section of the AMR presentation to highlight emerging topics that the data book could cover if funding is available based on requests from the stakeholders or insights from the PI.

Reviewer 8:
The future research plan appears to be logical.

Reviewer 9:
The reviewer needs more detail on the types of additional topics that will be covered moving forward.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The TEDB includes a number of datasets that provide a fundamental understanding of both the baseline and potential scenarios for national security, economic growth, affordability, and resilience of United States (U.S.) transportation systems, helping to fulfill one of the VTO Analysis Program's three broad objectives, creating and maintaining a strong foundation of data. The FOTW effort particularly focuses on spreading data driven conclusions on how DOE VTO is accomplishing its objectives.

Reviewer 2:
The project is very well aligned with VTO objectives, providing access to a consistent set of transportation energy data to researchers and the public.

Reviewer 3:
The Transportation Data Program seems well in tune with maintaining relevance to the user community and VTO.

Reviewer 4:
High quality data are the foundation of all other DOE research and projects. This is very important and highly relevant work.

Reviewer 5:
This project lays the foundation of the VTO Analysis portfolio pyramid structure. ORNL does an excellent job of keeping this foundation strong year after year. The reviewer stated the project team should consider adding a pop-up question on the DOE FOTW website to provide readers a direct opportunity to share what FOTW should be shown in the future.

Reviewer 6:
Data are the cornerstone of research and decision making in the transportation space. TEDB is one of the only comprehensive resources the community can access.

Reviewer 7:
The high adoption levels of the deliverables speak to its relevance.

Reviewer 8:
The project team provides supporting data that would have to be sourced independently for other VTO research. activities.

Reviewer 9:
The reviewer indicated no comments.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This reviewer indicated sufficient/excessive and explained that the budget is a bit higher than some of the other model development projects. It is not clear how much of the project budget is devoted to staff time to compile these outputs, staff time to serve as a liaison on other VTO projects, and access to private data sources.

Reviewer 2:
The PI has been doing this for decades and has a strong grasp of the complex web of connections needed to pull together such a large data effort.

Reviewer 3:
The team has an established approach in place and sufficient resources to achieve the milestones set in the expected timeline.

Reviewer 4:
It looks like data collection is getting more and more difficult because government agencies are discontinuing some programs and private companies are increasing price tags and data use restrictions. From this perspective, additional resources will be very beneficial. The reviewer suggested that DOE helps investigators address such challenges via an additional budget, as well as other innovative ways (e.g., partnership with private companies so that data can be shared at a relatively lower cost).

Reviewer 5:
Resources appear sufficient for the PI to meet stated milestones in a timely fashion.

Reviewer 6:
Funds seem sufficient to cover multiple updates to the TEDB and to continue with the FOTW efforts.

Reviewer 7:
The resources are sufficient.

Reviewer 8:
The reviewer offered no further comments.

Reviewer 9:
No further comment was indicated by this reviewer.

Presentation Number: van017
Presentation Title: ANL VTO Analysis Modeling Program
Principal Investigator: Michael Wang (Argonne National Laboratory)

Presenter

Michael Wang, Argonne National Laboratory

Reviewer Sample Size

A total of ten reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 90% of reviewers indicated that the resources were sufficient, 10% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

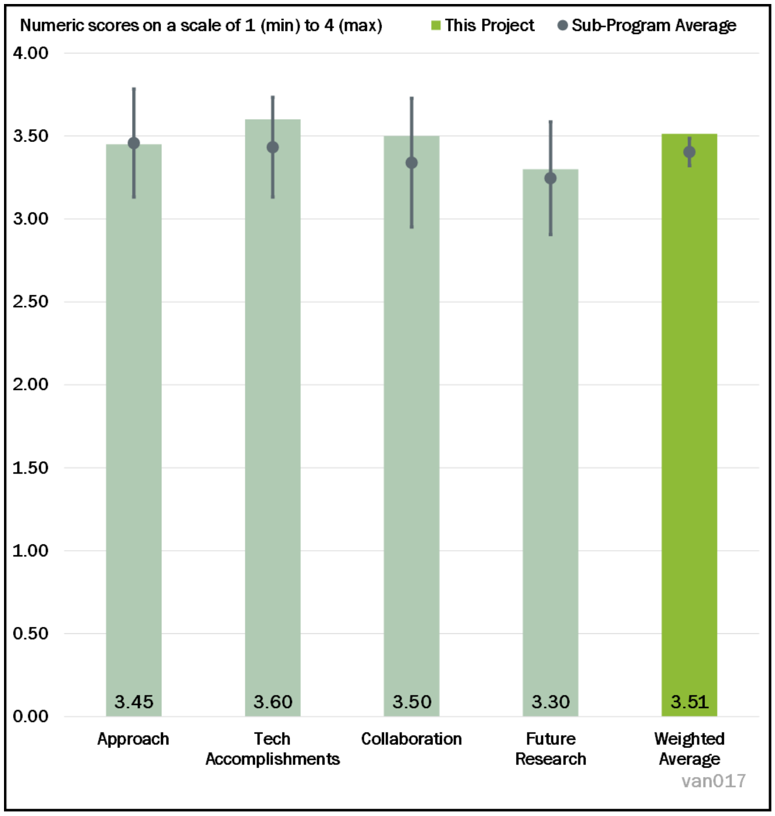

Figure 8-2 - Presentation Number: van017 Presentation Title: ANL VTO Analysis Modeling Program Principal Investigator: Michael Wang (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Continuously updating the Greenhouse gas, Regulated Emissions, and Energy use in Transportation (GREET®) models with the latest information and providing transparent updates, improvements, and assumptions is an excellent approach to help users evaluate energy and environmental impacts of vehicle and fuel systems. While the general approaches described for each of the current tasks are reasonable, the challenge acknowledged in the presentation that there is a “Need to address technology improvements and market changes as time progresses so that the effects can be reflected in GREET® benefits assessment” is especially important for emerging technologies and changing pathways. For Task 1, consider evaluating year to year variability of energy flows as well as time of day differences.

Reviewer 2:

The switch to a consumption-based electricity model is a step towards more accurately modeling overall greenhouse gas (GHG) emissions from electricity use. Collaborations with industry partners are helpful to incorporate relevant future technologies and flows of key materials [e.g., aluminum (Al), steel]

Reviewer 3:

Technical barriers include how to evaluate environmental sustainability; how to evaluate energy and emission benefits of vehicle/fuel systems; and overcoming inconsistent data, assumptions, and guidelines. The first two are explored in the project objectives; specifically, by expanding the analysis envelope to include key impactors like higher resolution electricity grid operations, automotive material supply chain flows, and emerging mobility options. It is unclear how the third barrier is addressed because it is not discussed. Slide 3 lists “developing transparent models,” but exposing the data, assumptions, and guidelines to the public is not necessarily overcoming inconsistencies. It is, perhaps, one step toward evaluating inconsistencies. What inconsistencies were overcome, and how?

It would be helpful if the presentation clearly described how the current work overcame each barrier. Slide 3 may have been an attempt but it is not convincing. The project addresses the barriers implicitly, but the presentation should clearly and explicitly explain how. Slide 19 presents a separate list of challenges and barriers that include some of the quad chart barriers and some others.

That said, the project has decently well-defined objectives, including modeling electricity generation and inter-plant/end-use emissions flow; evaluating the automotive steel and Al supply chain; and evaluating GHGs for emerging mobility. The approaches are all well designed and are “right-sized” to accommodate the level of uncertainty in data inputs. In particular, selecting a parametric investigation for objective three is more reasonable than assuming constant values for all parameters.

Reviewer 4:
The reviewer understood the need for these analyses and large modeling frameworks such as GREET®, but there is also quite a lot of disagreement and uncertainty in how certain metrics for life cycle assessment (LCA) should be accounted for. LCA is not an area of expertise for the reviewer, but the reviewer has read enough LCA studies to know about some of the disagreements. For example, many LCA studies about EVs get different results in charging emissions depending on whether the analyst uses average emissions factors versus marginal emissions factors. EVs charging on coal at night, for example, may have a larger emissions contribution compared to the calculation using average emissions in the region. It is unclear what the right choices are, in general, as choices tend to be content- and project-specific. The reviewer recommended providing some greater guidance for how to use these models and understand the assumptions associated with them, and that this should be part of a “user manual” that discusses what assumptions and settings people should consider depending on which type of analysis is being done.

Reviewer 5:
The presentation was focused on the objectives and the outcomes of the project which were clearly articulated with respect to consumption-based emissions and AV GHG emissions. The methodology was not adequately described to enable the reviewer to evaluate the progress made. As an example, it was not clear how GREET® LCA was enhanced to meet the project goals. More details on the derivation process of the consumption-based electricity mixes could have been provided.

Reviewer 6:
This reviewer noted the mission of providing a robust model in GREET® that is relevant and usable by the community. The reviewer would like to know more about how GREET® compares with other LCA models that are commonly used in government and industry, although this may be well outside of the project mission.

Reviewer 7:
The project team used good approaches, such as building on the GREET® model, creating a detailed data analysis, and collaborating with other DOE laboratories, U.S. Driving Research Innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE), and other industrial associations.

Reviewer 8:
The PI’s approach to performing the work is excellent. The project is comprehensive and moves GREET® modeling forward by adding important expansion components.

Reviewer 9:
The team makes good use of existing models to evaluate grid and materials impacts on LCA for vehicles.

Reviewer 10:
GREET® is one of the most widely used tools in transportation energy. The approach is well established and grounded in the realities in policy making.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The task-specific accomplishments for improving, expanding, and updating the GREET® models' evaluation of grid emissions, Al and steel flow, and cradle-to-grave (C2G) GHG emissions of emerging mobility options with connectivity and automation, all appear to be progressing successfully. As noted in the objectives section, it will be important to continue to assess changes to these areas over time and to incorporate additional detail when it is available.

Reviewer 2:
The project has hit major milestones with respect to updating data and model inputs, and annual model updates seem on track.

Reviewer 3:
The project has made substantial progress toward meeting its objectives, as shown in the milestone chart and as validated in the remaining slides. The data for electricity grid and emissions flow has been collected and analysis has been started (some results presented). Al and steel flow data and qualitative information have been collected. The AV LCA also appears to be complete and its report has been delivered to VTO.

Reviewer 4:
The accomplishments were clearly defined and presented in the maps that demonstrated differences between generation- and consumption-based electricity GHG intensities. Specific California GHG intensity examples are given as well as the emission flows across the United States. The technical accomplishments tied to AV technology emission estimates should be clear with respect to assumptions of AV operations (universal adoption or hybrid connectivity automation and a certain share of regularly driven vehicles?). The sensitivity analysis was helpful to uncover important parameters in GHG emission intensity estimation.

Reviewer 5:
The reviewer appreciated the two versions or approaches in the fuel cycle analysis and the vehicle cycle analysis supporting the C2G analysis.

Reviewer 6:
The consumption-based electricity mix work is very insightful and can help clarify many questions and debates. The reviewer suggested that the results be published as soon as possible. The U.S. automotive steel and Al work is also beneficial, but the reviewer inquired about its application and use in the GREET® model for future LCA: how those components imported to the United States should be addressed; whether trade policies will significantly affect future Al and steel flow; and if yes, how that will change model results.

Reviewer 7:
The PIs have made excellent progress within the first year of work. Future barriers to data accessibility should be targeted and new partnerships may need to be formed in order to get needed data inputs.

Reviewer 8:
Consumption-based emissions estimates will be critical to understanding the real-world sustainability impact of a given vehicle. Additionally, modeling emerging mobility options will help understand what the energy impacts of these technologies will be in the future.

Reviewer 9:
The results comparing generation-based and consumption-based electricity emissions are illuminating.

Reviewer 10:
The reviewer referenced prior comments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration with other experts is extremely important for a comprehensive model, such as GREET®. Please continue to collaborate with other institutions and users to thoroughly review the assumptions and validate the results of the models.

Reviewer 2:
The project has a number of different partners to address specific topics [e.g., U.S. DRIVE for vehicle automation, Environmental Impact Assessment (EIA) and EPA for emissions, industry associations for Al and steel]. The reviewer argued some incorporation of behavioral factors would be interesting to include in the emissions modeling. Many other groups and National Laboratories have looked at when most EV owners charge vehicles and incorporating that data could be have an impact on emissions, even if the emissions estimates are aggregated over a yearly or quarterly timescale.

Reviewer 3:
The project team appears to have collaborated with key relevant stakeholders, particularly U.S. DRIVE [e.g., original equipment manufacturers (OEMs)] for the AV research, EIA and EPA for the electricity grid research, and the University of Michigan and Al and steel industry groups for the supply chain research. It may be valuable to add other stakeholders to the AV research work, such as an AV development company (e.g., Cruise, Argo AI, Zoox, etc.) or TNCs (e.g., Uber, Lyft) to get a better grasp of how a robot-taxi fleet might operate. Additionally, the team should consider collaborating with other National Laboratories who are working on AV-related projects under Energy Efficient Mobility Systems (EEMS) or other funding.

Reviewer 4:
Collaboration efforts could be enhanced by integrating U.S. DRIVE and Systems and Modeling for Accelerated Research in Transportation (SMART) Mobility research outcomes in the C2G of automated vehicle estimation.

Reviewer 5:
The team demonstrates good collaboration with stakeholders.

Reviewer 6:
There are very good collaborations and coordination across project teams and other departments.

Reviewer 7:
Collaboration with external public and private partners appears to be well-established. In future reviews, the reviewer suggested identifying more partner organizations that could help with the needed data inputs that are not yet readily available to PIs.

Reviewer 8:
Collaboration seems appropriate.

Reviewer 9:
The team appears to work seamlessly.

Reviewer 10:
The reviewer indicated no further comments.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The planned and proposed future work is appropriate. In addition to expanding the consumption-based electricity analysis to the monthly and sectoral level, time of day variability for charging may also be important to consider.

In addition to continued evaluation of emerging technologies of interest, it would be extremely useful for the team to provide user-friendly access to the underlying sources and research for inputs to the model that are organized by topic on a website and document and are ideally cross-referenced from the GREET® Excel input and results areas and/or underlying cells.

Reviewer 2:
The project has a number of expansion items related to the consumption-based electricity analysis. While having monthly and sectoral-level data is helpful, it is also worth examining broader, intra-daily patterns of electricity use [especially for plug-in hybrid electric vehicle (PHEV) and battery electric vehicle (BEV) regional analysis]. Continued updates of material use, and flows seem to be on track, although the current policy situation may further distort normal market behavior.

Reviewer 3:
Each of the future research items are logical next steps toward meeting one of the first two objectives (electricity grid and steel and Al supply chain). There is also an open-ended "continue evaluation of emerging technologies of interest to VTO" goal. There are not any additional decision points, although the team does offer several remaining challenges and barriers.

Reviewer 4:
The researchers have identified a list of extensions of their work tied to GHG intensity. Additional recommendations are tied to time of day consumption-based emission intensity for EV recharging and extensive scenarios of AV operations for GHG intensity estimation.

Reviewer 5:
The reviewer encouraged consideration be given to new emerging technologies in medium-duty (MD) and HD in addition to the light-duty (LD) vehicle applications. It was a good plan to include e-fuels, net zero-emissions vehicles (NZEV) carbon fuels, and other relevant technology trends. The team alluded to future research to expand the sectoral level (Slide 21), but the reviewer would appreciate a more detailed description of which sectors are in the future research plan.

Reviewer 6:
The PIs have effectively planned future work by considering a wide variety of future tasks and recognition of barriers.

The reviewer suggested that more emphasis is placed on end user needs and how modeling could be simplified for web accessible tools based on geographic location, in particular evaluations of electricity generation. Please consider how this will replace or complement the DOE AFDC emissions from the plug-in hybrid geographic tool at https://afdc.energy.gov/vehicles/electric_emissions.html, which is currently widely used by end users and individual consumers when making EV purchase decisions.

Reviewer 7:
Documenting the impact of this research and incorporation into GREET® will be critical to understanding the changes in the model.

Reviewer 8:
The proposed future work is reasonable.

Reviewer 9:
The review offered a few questions and comments. Specifically, the reviewer inquired about the additional benefits envisioned to expand consumption-based electricity analysis to a monthly level and sectoral level. In addition, the reviewer asked if there is any plan to update other major components' LCA analyses. For example, with battery technology and the manufacturing chain quickly evolving, how can the team make sure previous results remain valid and applicable?

Reviewer 10:
No further comments were provided by this reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
It is valuable to continue to improve, expand, and update the GREET® models' evaluation of fuel and vehicle cycles for technology pathways of interest because the results of these models are used extensively to support other modeling and research projects, and to estimate potential energy and emissions impacts. In addition, the research that informs the underlying assumptions in GREET® contributes to the data and knowledge of emerging technology pathways.

Reviewer 2:
The GREET® model is a key tool to estimate C2G impacts of vehicle technologies and serves as a baseline for other analyses.

Reviewer 3:
The GREET® modeling framework provides fundamental data and analysis tools to accurately assess different technology options. This allows stakeholders (including the PI) to investigate transportation system impacts on energy affordability, energy security, economy, and the environment, which are all part of DOE VTO's mission. More specifically, it contributes to two of the VTO Analysis Program's three broad objectives: creating and maintaining a strong foundation of data, and building, maintaining, and exercising relevant analytical models.

Reviewer 4:
Very important and relevant work tied to emerging and efficient vehicle technologies emissions estimations is being conducted by the team. The work can be used by researchers focusing on the transportation energy domain for a more accurate externalities cost-benefit analysis of EVs.

Reviewer 5:
LCA work is becoming more and more important in helping understand different vehicle technologies' benefits and tradeoffs in the whole life cycle.

Reviewer 6:
This project makes important advancements to DOE VTO modeling.

Reviewer 7:
The reviewer noted energy estimates of vehicle technologies.

Reviewer 8:
GREET® has served as a foundation for data-driven decision making.

Reviewer 9:
The reviewer had no further comments.

Reviewer 10:
No further comment was offered by this reviewer.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources appear to be sufficient. However, the suggestion of additional documentation may require additional resources.

Reviewer 2:
Given the scope of the model developed and data collection, resources seem appropriate.

Reviewer 3:
The resources are sufficient to meet the stated milestones in a timely fashion; the team has been doing this work for a long time.

Reviewer 4:
The team should consider enhancing their analysis by integrating findings from SMART Mobility connected and autonomous vehicles (CAVs) and advanced fuel infrastructure (AFI) efforts before conducting the proposed LCA.

Reviewer 5:
Resources appear to be sufficient. PIs should continually reevaluate what can be accomplished in the overall project timeline.

Reviewer 6:
The resources are appropriate.

Reviewer 7:
The resources are sufficient.

Reviewer 8:
The resources appear to be sufficient.

Reviewer 9:
No further comments were provided by this reviewer.

Reviewer 10:
The reviewer had no further comment.

Presentation Number: van018
Presentation Title: Light-Duty Vehicle Choice Modeling and Benefits Analysis
Principal Investigator: Aaron Brooker (National Renewable Energy Laboratory)

Presenter

Aaron Brooker, National Renewable Energy Laboratory

Reviewer Sample Size

A total of ten reviewers evaluated this project.

Project Relevance and Resources

90% of reviewers indicated that the project was relevant to current DOE objectives, 10% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 90% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 10% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

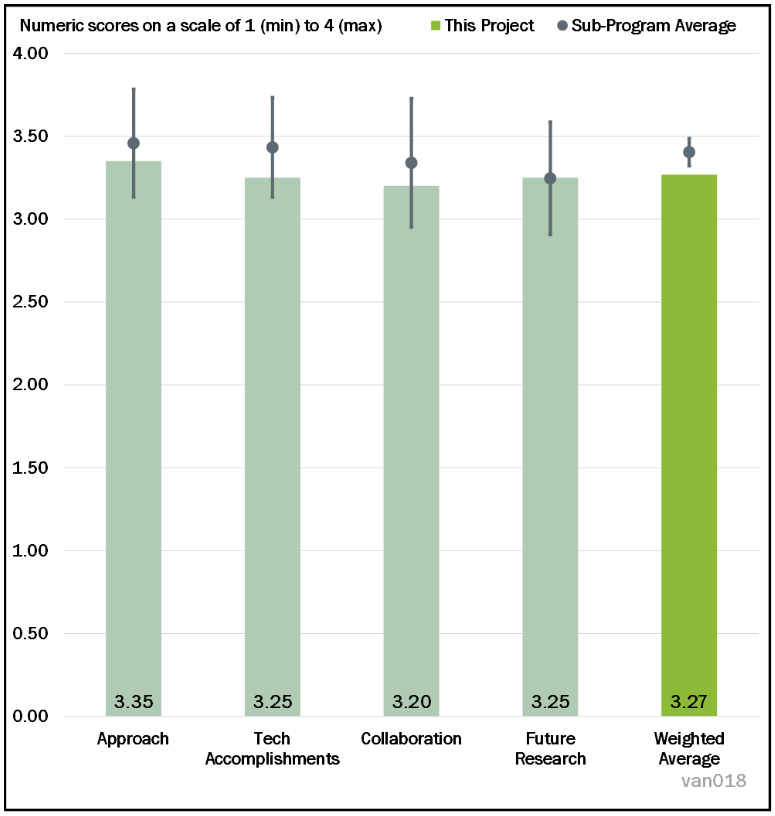

Figure 8-3 - Presentation Number: van018 Presentation Title: Light-Duty Vehicle Choice Modeling and Benefits Analysis Principal Investigator: Aaron Brooker (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The technical approach is presented in great detail. The team should better specify how the barriers that are identified will be captured in the existing Automotive Deployment Options Projections Tool (ADOPT) framework. For example, it is not clear how multi-vehicle household choices are expected to be modeled or how home charging unavailability will be integrated (the team could specify these as penalties or benefits added in the existing framework).

Reviewer 2:

The approach is clearly stated and demonstrates progress towards fulfilling objectives of the program.

Reviewer 3:

The team has a good approach to employing the established ADOPT model and discussing and reviewing model results with stakeholders. Continuing to improve the ADOPT model is very good.

Reviewer 4:

Given a transition from the initial project at another laboratory, NREL has done an excellent job at taking on the work, addressing technical barriers, and designing a feasible effort.

Reviewer 5:

The approach to estimating impacts of vehicle technology R&D seem reasonable and incorporate different policy mechanisms that could drive different scenarios of deployment.

Reviewer 6:
It is difficult for this modeling exercise to keep up with the fast-changing pace in vehicle technologies and consumer preference. It is not clear what the value proposition is.

Reviewer 7:
Using the ADOPT to run scenarios that meet DOE technical targets is a reasonable approach. As noted under "proposed future research" in the presentation, it is important to conduct sensitivity analyses on underlying assumptions in the model. Similarly, it may be valuable to characterize the uncertainty of underlying factors and relationships in the model and to present error bands and confidence intervals where possible, especially for those factors that have high variability in the literature and in future projections.

As mode choice continues to expand, it may be important to consider how travel outside privately-owned passenger vehicles impacts LD vehicle sales, energy use, and emissions.

Reviewer 8:
The reviewer stated that the overall process of examining different models and then applying different policy and regulatory conditions is a good workflow, but is less convinced on some of the technical models. The reviewer is a bit skeptical of the battery model, especially because there would be spillover effects between plug-in and "conventional" hybrid vehicle battery storage technologies. Today, many hybrid electric vehicles (HEVs) have switched over to lithium-ion (Li-ion) batteries, which are very similar to the batteries in PHEVs, so the fact that one market would grow while the other stagnates does not intuitively make all that much sense. The reviewer is also a bit concerned about the age of the validation data. Slide 11 presented data from 2016, which is before Tesla's Model 3 and the Chevy Bolt were in production, along with many other vehicle models, so it may be worth further validation of the split between PHEV and HEV sales. Incorporating other factors- like the planned inclusion of charging availability- may help to clarify the split between the two technologies.

Reviewer 9:
A technical barrier is rigorous modeling and applied analysis is needed to assess program benefits and inform portfolio planning related to research and development (R&D) funded by various VTO focus areas. The project clearly aligns its objective with overcoming this barrier and uses the ADOPT modeling framework to meet the objective. The ADOPT approach itself is well designed and feasible; it is an existing modeling framework that has been used for similar purposes in the past. The approach follows VTO's traditional benefits analysis process, which has proven to be helpful for DOE staff managing research programs (e.g., to run a "no program" or baseline case, collect VTO technology targets, apply those targets to create a "program case," run the "program case," and compare "program" and "no program" to estimate VTO's impact on the market).

It is not clear if the baseline and no-program case has been validated against other modeling frameworks, such as EIA's National Energy Modeling System (NEMS). Perhaps it is not a necessity, but it would be helpful for stakeholders to see how the baseline compares to other baseline estimates. The fact that both ADOPT and FastSim are open source is a big source; it means the analysis is reproducible and (mostly) transparent.

As far as suggestions, the reviewer assumed this is already being done, but it would be great if the final report included a scenario where all of the programs were successful. It would also be helpful to show vehicle miles traveled (VMT) shares rather than (or in addition to) sales shares

One note (which does not fit in the other categories) is that the slides are a little scattered and difficult to follow. It would be helpful to structure them a little more logically.

Reviewer 10:
The reviewer stated a fundamental question as to whether it is possible at all to make a useful forecast of something like technology adoption in vehicles beyond a decade into the future. For those who need a forecasting tool to use to base decisions on, this one appears to be well thought out. The one thing the reviewer

would have liked to see is some fundamental bounds on the possible future outcomes. For example, if the use of internal combustion engine (ICE) vehicles in 2021 was banned and somehow automakers were able to respond and supply the same number of EVs as there are ICE vehicles today, what would the overall fleet look like in 2030? What percentage would be EVs? How much petroleum and energy usage would the vehicle fleet use? This would be a useful calculation as a lower bound to what can be achieved. Likewise, what if all EVs disappear and all that is left are ICE vehicles for the next 30 years? That would be an upper bound. Every single scenario run should then fall between these bounds. The reviewer suggested making sure to note those bounds on every output scenario to place it in context. Basically, there are some simple assumptions that can be made to create some boundaries, and then all of the simulations that are run can be placed within a bounded context.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The team demonstrates concise accomplishments with respect to electrification success sales comparison. The technical backup slides demonstrate how the model choses the bestselling vehicle option based on the ADOPT cost-benefit analysis and specifies all of the assumptions made. The team's progress is aligned with expected accomplishments and performance indicators are met according to the ADOPT alternative fuel vehicle sales findings.

Reviewer 2:
Progress appears to be on track and there is a substantial demonstration of progress on the LD vehicle side. MD and HD vehicles are in early stages of development. The reviewer is looking forward to further output and progress in this regard in future reports and suggests anticipating the technology trends in the commercial vehicle space. There seems to be a close connection to NREL in developing and demonstrating continued relevance in this sector, as has been demonstrated thus far in the LD sector.

Reviewer 3:
Significant progress has been made on this project by the PIs in its first year at NREL and performance indicators appear positive.

Reviewer 4:
The collection of historical data as well as scenario runs provide valuable data to help understand the role of R&D in energy savings.

Reviewer 5:
Progress, including model improvements and the development and execution of scenarios that are based on DOE technical targets, seems appropriate.

Reviewer 6:
Progress is satisfactory and results provide a lot of insights about future technology improvements' benefits.

Reviewer 7:
The project seems to progress as planned.

Reviewer 8:
The model interface has been improved, and the simulation time is reasonable for a model with this breadth. Some initial scenarios have been run to support benefits results of different vehicle technology pathways. The reviewer said that continued refinement of some of the assumptions, especially with help from key technical offices [e.g., the Bioenergy Technologies Office (BETO), the Hydrogen and Fuel Cells Technology Office (HFTO)] will be critical to ensuring that the input assumptions are aligned with actual program targets and current technology pathways.

Reviewer 9:
The project appears to have made sufficient progress to meet all of its milestones, and the last steps are to compare the no program and program case runs and then write a final report. That said, it is not clear whether the project team has received final confirmation and go-ahead from VTO, BETO, and HFTO to publish the results. This is often the lengthiest step of the process (the "churn"), as some technology managers may want to search for technical targets or assumption adjustments that produce positive market results. Hopefully, the team has locked in vehicle attribute targets and other assumptions (e.g., bar changes after a specific date) to prevent multiple adjustments and schedule delays, especially since the model takes considerable time to run. This could be exacerbated by the final "combined program success" run, where the reviewer assumes either fuel cell vehicles (FCVs) or EVs win out, even though both meet aggressive technical targets. It will be (or perhaps already is) a precariously fine line to walk.

Reviewer 10:
The reviewer referenced prior comments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This process inherently requires a lot of collaboration with DOE (e.g., VTO, BETO, HFTO), and the NREL team appears to be doing that actively. The team also appears to be leaning on ANL- the previous owners of some of this work- to help ease the benefits analysis baton pass.

Reviewer 2:
There is good collaboration with NREL, ANL, VTO, and other stakeholders.

Reviewer 3:
The reviewer observed good collaboration with other DOE laboratories and industry via DOE technology managers.

Reviewer 4:
The work seems to be well distributed among partners.

Reviewer 5:
The collaboration appears to be adequate.

Reviewer 6:
The team's interactions could be strengthened with SMART Mobility AFI and other SMART collaborations to integrate home and public charging projection in the ADOPT platform and capture interdependencies with AFI and estimated vehicle projections.

Reviewer 7:
Collaborating with other experts and benchmarking results against other models will continue to be critically important for refining and validating consumer preference models, like Adopt.

Reviewer 8:
The project team has worked with ANL to incorporate fuel efficiency technologies available and has ongoing meetings with BETO and HFTO. Incorporating those programs earlier in the development phase would have helped some of the preliminary results and should be completed before publishing a final outcomes report, especially since many scenarios are centered around a technology's success.

Reviewer 9:
It would be helpful to have more information on how the PIs are engaging industry beyond only inputs for targets (e.g. U.S. DRIVE). How this project is serving the needs of the other DOE program offices outside of VTO would also be helpful.

Reviewer 10:
The reviewer indicated no comments.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The project has some good future model changes, including aligning with Annual Energy Outlook (AEO) fuel prices and emissions, updating to the latest fuel economy regulations, implementing multi-vehicle household considerations, and accounting for COVID-19 impacts. However, as the AMR presentation mentions, the project involves recurring work, so model development is more of a value-add than a necessity. The team will need to complete the same task (e.g., update inputs, complete benefits analysis, write report) every year for the duration of the project. That is included in the listed future work, so the future work plan is sufficient.

Reviewer 2:
The reviewer would like the team to continue updating the model with the latest and best assumptions from well-established projections, literature, and research, and continue to benchmark segmented results against the latest fleet data. The willingness to pay studies may need to be updated frequently, especially for concepts about nascent technology. As suggested on Slides 17 and 18, breaking out preferences in multi-vehicle households for concepts such as BEV range would be a useful addition to the model's design.

Reviewer 3:
The proposed research covers some key areas with respect to policy uncertainty and fuel prices. The reviewer is a bit less concerned about the short-term effects of COVID-19 on transportation behaviors because some of the most dramatic reductions in transportation have already sprung back to near normal levels, although income effects may have a more substantial impact (similar to other recessions). It might be worthwhile to look at TNC policies that push for electrification, either in parallel with or absent to government policies.

Reviewer 4:
Newer transportation trends will need to be accounted for in future analyses, which this project seems to do.

Reviewer 5:
Future work is a logical extension of the current work, and both are expected to enhance the approach and result in more accurate accomplishments. Go/no-go decisions are noted in the proposed future analysis, but barriers and alternative development pathways are not emphasized in the proposed future research.

Reviewer 6:
The plan for future research is clear and meaningful. No further changes are suggested beyond those already stated.

Reviewer 7:
The proposed future research topics such as fuel price sensitivities, home charging availability, multi-vehicle household impact, and transportation mode shifts are all of interest and relevant. Regarding charging infrastructure, the reviewer suggested to also consider impacts of destination charging and the availability of direct current (DC) fast charging. Given the increasing interest in hydrogen (H_2) fuel cell vehicles, it might be good for investigators to also look at the impacts of H2 refueling infrastructure availability. The reviewer

suggested continuous efforts to improve the ADOPT model to make it more user-friendly (e.g., documentation and user-interface, technical support, etc.) because this is a very powerful tool. The reviewer downloaded the model and wanted to give it a try, but found that the installation step is a bit lengthy and the user interface is not very self-explanatory to new users.

Reviewer 8:
The PIs have effectively planned for future work, however alternate development pathways are unclear.

Reviewer 9:
The proposed future research is faced with many uncertainties and it is not clear what direction the team plans to take.

Reviewer 10:
No further comments were offered by this reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
This project supports DOE's objectives of estimating the energy and emission benefits of vehicle technology research.

Reviewer 2:
With the proper collaborations between offices, the project helps to fill a gap between fundamental technology research and overall potential impact on the transportation sector.

Reviewer 3:
This is an essential piece of the VTO Analysis Program portfolio, and clearly contributes to all three of the programs objectives: creating and maintaining a strong foundation of data; building, maintaining, and exercising relevant analytical models; and executing insightful integrated analyses that provide a greater understanding of critical transportation energy problems.

Reviewer 4:
The project directly supports DOE and VTO objectives with a LD benefits analysis that has the capability to account for several techno-economic pathways and scenarios.

Reviewer 5:
This is very relevant work.

Reviewer 6:
The development of modeling that can inform the energy and emission impacts of VTO-supported technologies is a foundational need for DOE.

Reviewer 7:
The project highlights the importance of R&D in vehicle technology that happens at DOE and VTO.

Reviewer 8:
Even though the research question is relevant to DOE objectives, it is not clear how the results from the research can inform decision making going forward.

Reviewer 9:
This reviewer had no further comments.

Reviewer 10:
No further comments were provided by the reviewer.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The team resources are sufficient to complete the work; The PI and others at NREL have considerable experience developing and running ADOPT, as well as considerable experience with advanced vehicle technologies and transportation energy. Additionally, as mentioned before, the team who previously did the work at ANL is available to help "hand off."

Reviewer 2:
The team has access to resources that will assist them with successfully achieving the stated milestones. Collaboration extensions with feedback loops from SMART Mobility project leads could be also fruitful.

Reviewer 3:
The resources appear to be comparable to other projects of this size.

Reviewer 4:
Given the scope of the model developed, the resources seem appropriate.

Reviewer 5:
The resources appear to be sufficient to accomplish milestones on a reasonable timeline.

Reviewer 6:
Finances seem appropriate for a project of this scope.

Reviewer 7:
The resources seem sufficient based on the current work proposal. However, as suggested in Question 8, it will be good to further improve the capability and user interface of the ADOPT model, increase the user base, and provide a more detailed documentation on technology support. If this is included in future work, then the investigators may need additional resource support.

Reviewer 8:
No further comments were provided by this reviewer.

Reviewer 9:
The reviewer indicated no further comments.

Reviewer 10:
The funding seems excessive.

Presentation Number: van023
Presentation Title: Assessing Energy and Cost Impact of Advanced Vehicle Technologies
Principal Investigator: Aymeric Rousseau (Argonne National Laboratory)

Presenter

Ram Vijayagopal, Argonne National Laboratory

Reviewer Sample Size

A total of ten reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

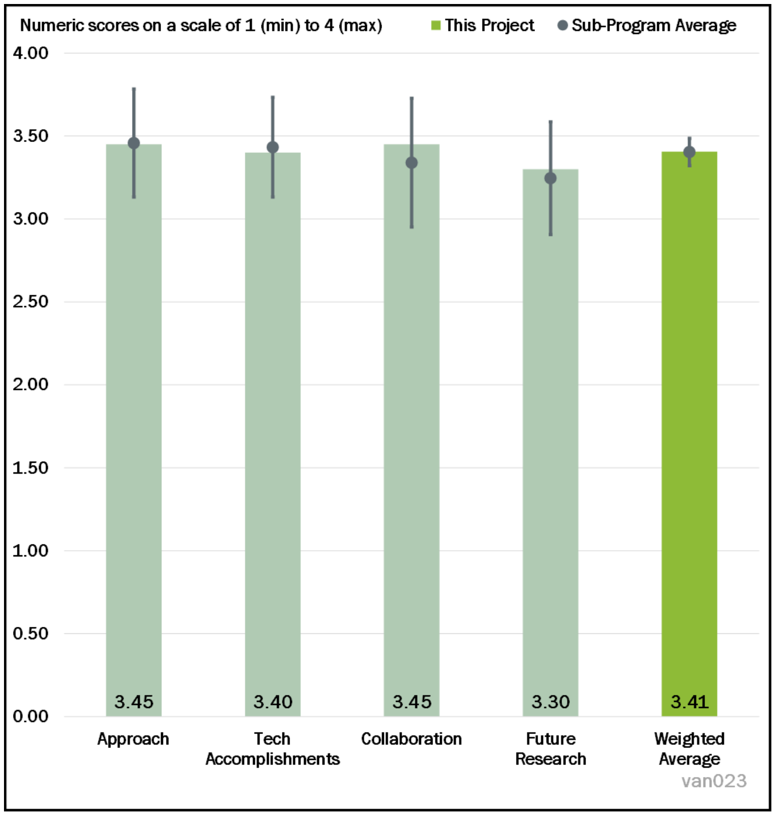

Figure 8-4 - Presentation Number: van023 Presentation Title: Assessing Energy and Cost Impact of Advanced Vehicle Technologies Principal Investigator: Aymeric Rousseau

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Regarding Task 1, the reviewer offered kudos to the team for taking on the difficult topic of disaggregating effects for which the order of application and secondary effects are relevant. The approach- showing a range of values with the minimum being that all technologies are applied- appears to be sound. As the team is no doubt aware, it will be both challenging and important to clearly communicate the range of results and the associated ranges of uncertainty. Key updates, such as those described in Task 2, are particularly important for Autonomie to remain relevant as things change.

Reviewer 2:

The project has already made good use of computing resources and process automation to compile enormous amounts of data about possible technology combinations. Increasing the vehicles and technologies included- with a focus on those responsible for the most miles traveled and fuel consumption- is a good approach to balance the need for more vehicles against the time required to incorporate new resources. Including uncertainty around individual contributions and providing some information about the pathways for technology adoption that account for differences will be helpful in future assessments of fuel economy regulatory costs.

Reviewer 3:

The project specifically aims to address four barriers from Page 2.2-1 of the 2010 VTO Multi-Year Program Plan ([MYPP] 2011-2015): manufacturer's aversion to risks inherent to new technologies (A); constant advances in technology (F); compute resource cost (B); and sufficient and accurate modeling methodologies (E).

Its approach to addressing these barriers (two tasks) follows: developing a generic process that is flexible across size, class, and vocation, to quantify energy and cost impacts of specific vehicle technologies and applying it to one class (mid-size cars); and updating assumptions, models, powertrain architectures, and sizing methods for light-duty vehicles (LDVs) and medium- and heavy-duty vehicles (M/HDVs) to support the VTO benefit analysis. The data will then be disseminated to relevant stakeholders for a wider research use.

Specifically, the team is expanding to assess individual technology impacts by simulating all technology combinations- in different order permutations- to investigate the impact of each and of different combinations. This approach seems reasonable and appears to be feasible based on the past applications of Autonomie.

- Barrier 1: This approach addresses manufacturers' aversion to new tech investment by clarifying the different potential performance, cost, and efficiency impacts each technology (and combination of technologies) has on different vehicle classes, powertrain types, and vocations.
- Barrier 2: This approach addresses the constant evolution of technology by updating assumptions to match the latest information and providing that data (and results) to stakeholders.
- Barrier 3: This seems to be a very computationally expensive approach, but the reviewer is not sure there is a better way to include all technologies (individually).
- Barrier 4: The approach implements a modeling methodology that is proven and has been trusted by stakeholders (including DOE VTO) for a number of years. This project, in particular, includes several smaller upgrades to the model, which help make the model more accurate to real on-road performance.

Overall, the project approach addresses all four of the technical barriers (as listed in the presentation and below). One potential issue is dissemination of the data and results. Autonomie is proprietary, and it is not clear how much of the input assumptions and outputs will be publicly available to a wider research audience.

Reviewer 4:
The approach seems methodologically solid. Data driven simulations can be accelerated through machine learning (ML) so that the computational process can be faster and reproducible by others (e.g., researchers, academics, the industry). The technical barriers are addressed through high performance computing (HPC) and the further proposed steps seem feasible.

Reviewer 5:
There is a comprehensive approach including a wide variety of LD, MD, and HD vehicle types and duty cycles.

Reviewer 6:
The team has a good approach.

Reviewer 7:
The PIs have developed a solid approach to addressing technical barriers. Building off of years of work, the PIs recognize what is feasible with the allocated resources.

Reviewer 8:
A technology combination analysis will be useful in determining energy impacts of technology packages.

Reviewer 9:
The Autonomie approach is well recognized.

Reviewer 10:
The reviewer really liked that this model gave component-specific benefits and that the implementation order was considered. These are critical considerations to make this model track closer to reality. The reviewer also appreciated some of the other innovations added, such as the inclusion of additional sizing criteria. The only suggestion would be to continue engaging with OEMs to try and accurately map how decisions are being made to their associated elements in the model, especially in things like the ordering of technology implementations.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The FY 2020 milestones chart looks reasonable. It is nice to see that the team is developing graphical methods to explain the order of contribution and/or range of values for each component in Task 1. For Task 2, the addition of new classes of MD and HD vehicles representing 85% of the fuel consumption and additional sizing criteria is commendable.

Reviewer 2:
The team has made great progress in expanding the technologies included in the model and showing uncertainties of individual technology contributions. Of the projects reviewed, the reviewer stated this one makes the best use of HPC resources and data management practices, which will ultimately make it easier to incorporate new technologies, so continuing with this effort is key.

Reviewer 3:
Individual and cumulative component contributions for the range of vehicles demonstrated here is impressive.

Reviewer 4:
Progress in both task areas has been made in accordance with planned milestones.

Reviewer 5:
The project appears to make progress as planned.

Reviewer 6:
The project seems to be on schedule with significant technical accomplishments. In particular, the component specifications determined to meet and exceed the set requirements would be important literature and can impact future vehicle technology advancements. However, it is important to put forward good documentation and a platform for results reproducibility to help data and methods diffusion for the industry and others.

Reviewer 7:
Very good progress has been made and many insightful results have been produced. Autonomie has become a key data source and reference for many related works. The percent complete reported on Slide 2 in the timeline section is 20%. Considering this is a four-year project and this is the middle of year two, is this percentage a little behind? Investigators might further clarify.

Reviewer 8:
Good progress is demonstrated on a range of vehicle types and duty cycles. The reviewer would appreciate more detail on the factors effecting the light weighting cost impact, both increased cost and lower cost. There is good explanation that secondary benefits can often save cost, and this should be discussed further in the presentation in the future.

Reviewer 9:
At this point, the project team should be done setting up the process and identifying technology combinations, and nearly done gathering VTO targets and performing the large-scale simulation. It is not clear how far along either of the latter two tasks are, although it is clear that progress has been made (generally).

Technical accomplishments include completion of the analysis of fuel consumption and cost impacts of individual technologies for LD HEVs, PHEVs, and BEVs, and expansion of the number of defined truck models and improvement of the truck sizing methodology in Autonomie. The team is still working on gathering VTO targets (Quarter 3 milestone) and appears to have identified technology combinations (Q2 milestone).

The team has made a considerable amount of technical progress, particularly in updating assumptions and improving the model sizing methodology. That said, there is not really a clear crosswalk between the tasks and milestones and the actual accomplishments. The accomplishments- assuming what is shown has all been completed since Q1 of 2020- are impressive, but there is not a clear line of logic (e.g., technical accomplishment X meets milestone A, which marks the completion of Task A.1).

Reviewer 10:
The reviewer indicated no further comments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration and peer review are particularly important for developing inputs, assumptions, and algorithms for a complex simulation model. The reviewer suggested working extensively with a broad spectrum of experts.

Reviewer 2:
The project seems to have good collaborations and stakeholders that are actively engaged with the use of the tool and results.

Reviewer 3:
The reviewer observed very good collaboration across teams among DOE laboratories as well as industry partners.

Reviewer 4:
This is a very well fleshed out collaborative effort with a good distribution of research tasks and stakeholder engagement.

Reviewer 5:
The collaboration appears to be adequate.

Reviewer 6:
There are excellent collaboration prospects with U.S. DRIVE and industry, other National Laboratories, and research organizations. The reviewer expected more collaborations with academia for state-of-the-art components integration.

Reviewer 7:
There is good collaboration with industry, government, and stakeholders. The reviewer encouraged the project team to continue seeking industry input to maintain relevance to current and future technology trends.

Reviewer 8:
The PIs report improvements in the collaboration. More work may be needed to ensure that the end user feedback is being incorporated into the model design. In particular, it will be helpful to know, in the next update, how user testing and surveys are being used to inform the Autonomie end user interface.

Reviewer 9:
There appears to be collaboration between the project team, stakeholders, and partners, particularly DOE VTO managers, the U.S. DRIVE, 21st Century Truck Partnership (21CTP), and the National Highway Traffic

Safety Administration (NHTSA), but there is very little mention of the benefits from said collaborations beyond bullet two in the summary slide. It would be helpful to document a little more clearly how inputs from these partners are "continuously collected," perhaps by providing a frequency (e.g., monthly check-ins or something similar). The reviewer understood that input is required in some sense (e.g., collecting VTO targets), but documenting the collaboration would be beneficial.

Reviewer 10:
This reviewer indicated no further comments.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The proposed future research looks reasonable and logical. As noted on Slide 21 (Future Research), because electrified powertrains are in an early stage for trucks, the models will need to be updated frequently with new technology assumptions. Also described on Slide 21, the team's plan to provide a database of vehicle characteristics along with the related assumptions will benefit the broader research community and will facilitate review of this model. It is important to maintain a clear and well-organized database of underlying assumptions and methods so that researchers can continuously review the model, especially for emerging and evolving technologies.

Reviewer 2:
The focus on HD trucks is a good area to include, given the impact on overall emissions. The reviewer would potentially include a plan for retiring technologies if the industry is moving away from certain technology options, and would create documentation around criteria for retiring technologies that are no longer in use, in addition to documenting that in publications.

Reviewer 3:
PIs have planned for future project work with reasonable objectives.

Reviewer 4:
Future research is well planned but additional background is required regarding the barriers expected to be faced in this process.

Reviewer 5:
Future research plans are clearly stated and continues to be relevant to evolving technology trends. The reviewer is looking forward to future results in TCO models. Work from the American Transportation Research Institute (ATRI) report is referenced, but it is not clear if this represents any modeling of future impact, or if this is solely a report of demonstrated benefits from in-use technology adoption (e.g., currently available technologies as opposed to future proposed technologies that are not yet in service).

Reviewer 6:
Starting to pay more attention to MD and HD vehicles is a good start. It will be great if- for the VTO benefits analysis- investigators can provide some sensitivity and scenario analyses whether some of the targets are only partially met (it is probably too optimistic to assume that all of the targets will be met at the same time). If the investigators can come up with a most probably scenario, that will also be very helpful. In addition, the reviewer would like to know if any review work comparing how DOE has historically met targets and how that affects projections made by Autonomie exists.

Reviewer 7:
PIs have planned for future project work with reasonable objectives.

Reviewer 8:
EV modeling and public access to the database of vehicle characteristics and assumptions will be important to the success of this project.

Reviewer 9:
It is important to investigate electric trucks.

Reviewer 10:
The future research slide lays out some excellent reasoning for this work and a few next steps, but it does not clearly link up with where the project currently stands. Instead of focusing on justifying the current work, the future research should focus on what the team will specifically be focusing on in the (near) future. From the project presentation, it looks like future research should include topics such as finishing collecting VTO targets; completing vehicle powertrain sizing; estimating fuel consumption and TCO impacts via simulation; and publishing summary reports. Perhaps things like automating the process to reduce simulation time and investigating other potential approaches to reduce the number of required simulations for a single technology could be valuable as well.

Reviewer 11:
No further comments were offered by this reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
To establish priorities, it is important that DOE is able to estimate the potential disaggregated energy consumption benefits and the costs of technology targets and specific vehicle technologies.

Reviewer 2:
The project provides comprehensive resources to assess the impact of specific technology adoption on overall vehicle efficiency, with detailed information about how adoption pathways affect the overall impact. The data is one of the most comprehensive and can support other technical and policy analyses.

Reviewer 3:
This project specifically quantifies the impacts of specific (and groups of) technologies funded by DOE VTO, which clearly aligns with at least two of the VTO Analysis Program goals: assist VTO in prioritizing technology investments and inform research portfolio planning; and support quantitative assessment of vehicle and mobility technology impacts.

Reviewer 4:
Well aligned objectives with the DOE and VTO research portfolios were presented. Future research in creating ties between TCO and optimal component combinations will be of great importance.

Reviewer 5:
This is very relevant work, and many other projects and works rely on Autonomie work results.

Reviewer 6:
Quantification of the fuel saving and total cost of ownership benefits of VTO funded technologies is foundational to the VTO Analysis Portfolio.

Reviewer 7:
The project highlights the individual and cumulative impacts of key energy efficient technologies.

Reviewer 8:
It is important to investigate powertrain technologies.

Reviewer 9:
No further comments were provided by this reviewer.

Reviewer 10:
The reviewer indicated no further comments.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources for a complex and ongoing project are difficult to assess, but the budget is in scale with other similarly sized projects, and the project appears to be completing its goals.

Reviewer 2:
Given the scope of the project and its ability to build on previous years of work, the resources seem appropriate.

Reviewer 3:
The team has sufficient access to resources. Collaborations with the industry and drivers would strengthen the understanding of TCO.

Reviewer 4:
Time and financial resources are sufficient for PIs to successfully complete the work.

Reviewer 5:
Funding seems sufficient for a project of this size.

Reviewer 6:
The funding is sufficient.

Reviewer 7:
Resources look sufficient for now.

Reviewer 8:
The staff resources appear to be sufficient in terms of expertise. It seems like quite a bit of work, especially because this team is doing a number of other projects using Autonomie. The dollars are certainly sufficient for the level of effort.

Reviewer 9:
No further comments were provided by this reviewer.

Reviewer 10:
The reviewer indicated no further comments.

Presentation Number: van032
Presentation Title: Tracking the Evolution of Electric Vehicles and New Mobility Technology
Principal Investigator: Joann Zhou (Argonne National Laboratory)

Presenter

Joann Zhou, Argonne National Laboratory

Reviewer Sample Size

A total of ten reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 60% of reviewers indicated that the resources were sufficient, 20% of reviewers indicated that the resources were insufficient, 20% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

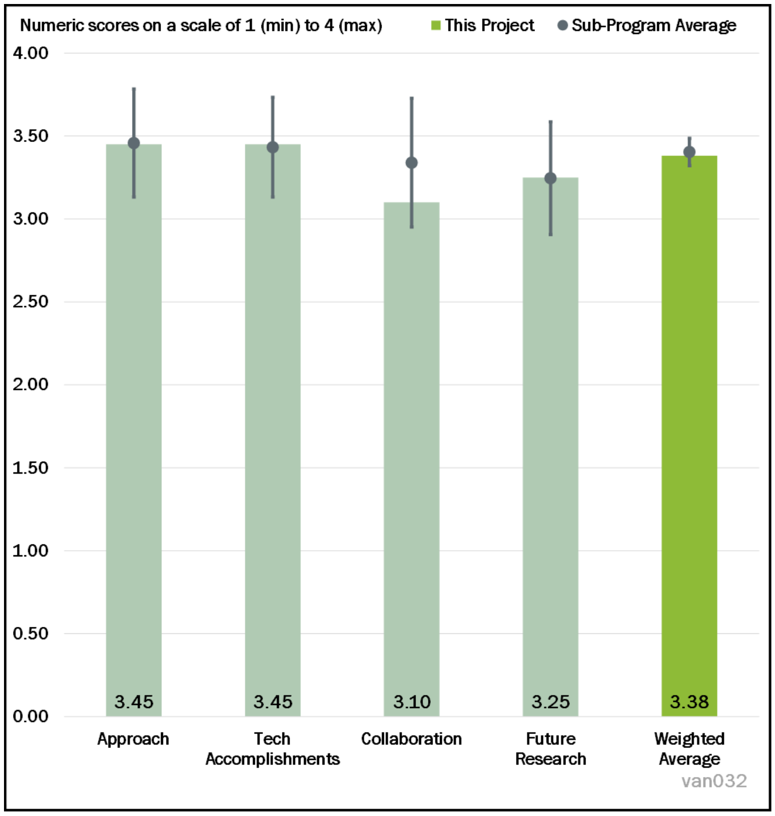

Figure 8-5 - Presentation Number: van032 Presentation Title: Tracking the Evolution of Electric Vehicles and New Mobility Technology

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Gathering, summarizing, analyzing, and publishing EV and new mobility adoption data is a useful process that helps to inform analyses and modeling for a variety of stakeholders.

Reviewer 2:

The data included in this analysis make use of multiple formats, which helps accessibility for other researchers. The reviewer stated there are some challenges given the reliance on private sources for data, both in terms of formatting challenge and the cost for accessing the data.

Reviewer 3:

The reviewer really appreciated that this research is being done. There is very little publicly available data on items like EV sales, and even less on the specifications of different EV models. Keeping track on emerging trends in some of the underlying technologies now will be important for identifying potentially new trends that could be important to incorporate in other related models.

As the reviewer suggested in a review for another study, it would be worth spending some time with a data visualization expert to improve most of the charts that are being published using these data. Many are quite poor and leave the reader without any important insights. Data visualizations translate raw data into insights, and good visualizations can have dramatic impacts on decisions and actions.

Finally, one other potentially interesting area that could be examined with these data is how trends are varying by region or nation. For example, it is known that China is leading the world in EV sales, but how are Chinese

EVs competing when it comes to technological improvements, such as vehicle efficiency? The reviewer stated it could be really important to dig into these types of questions as the locus of automotive innovation could be shifting away from the "west" [with ICEs] and towards China (with EVs).

Reviewer 4:
The approach is good.

Reviewer 5:
After many years of maintaining the work of the electric mobility market data effort, the PI continues to address the identified technical barriers.

Reviewer 6:
The approach is sound, and the project team does an excellent job of tracking LD by EVs in the market. It may be time to consider further expanding work to include MD and HD commercial vehicles [and LD connected vehicles (CV)] as these technologies are beginning deployment. While the population is still small, many OEMs and suppliers have entered the market with announcements and planned technologies in the last year or two.

Reviewer 7:
The highlighted approach will provide a comprehensive picture of e-mobility in the United States.

Reviewer 8:
The data aggregation approach is key to situational awareness.

Reviewer 9:
The approach is presented briefly but comprehensively. Few technical barriers are presented, and it is not clear what the next steps of this project are related to. The approach should also emphasize the importance of preparation of the e-drive sales data for DOE VTO and other offices' models.

Reviewer 10:
The technical barriers are providing quality data on electrification and new mobility technology and responding to VTO and external stakeholder queries. The project approach clearly addresses these barriers by aiming to collect and disseminate data and information on EV sales, attributes, and news, as well as micromobility market and usage. The project is well designed; The methodology and approach are logical and straightforward (e.g., identify, collect, clean, analyze, disseminate), and appears to be feasible under the assumption that the data continues to be available. Now that the team is using Wards data, data availability fails to be an issue any longer, although Wards does not allow the data to be published publicly (as far as the reviewer knew).

A side note is that this project appears to have realigned itself to provide significantly more valuable data and analysis than previously. In past years, it appeared that the PI and team pulled sales data from hybridcars.com and added it to an Excel file to distribute). The monthly e-drive sales spreadsheet has been very disorganized in the past, especially compared to interactive public websites like the Alliance for Automotive Innovation's interactive dashboard (https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/), but the addition of reports on (assuming sales-weighted) electricity consumption rates, electric range, and cumulative energy and emissions impacts is beneficial. Venturing into shared micromobility is likely valuable for VTO and other DOE staff who want to understand the industry and its potential impacts on traditional modes of transportation.

One comment on the visualizations is that the old format—as seen on the ANL sales update website—is borderline impossible to interpret. The reviewer was not sure that it was helpful to present a stacked area plot with so many data series. Developing a basic dashboard like the one linked above would be a very light lift and would make the data and analyses much more accessible.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The publication of data and reports appears to be on schedule.

Reviewer 2:
To date, projects have been on time, and efficiency improvements and specific technologies and battery chemistries are periodically documented. It would be great to see more information compiled on a monthly and quarterly basis and available in downloadable formats (e.g., Excel, comma-separated values [CSV]).

Reviewer 3:
The accomplishments are well established. Monthly and quarterly sales are important historical data that serve as inputs in several models. Greater spatial granularity (e.g. state-level analysis) would be of interest to the data users.

Reviewer 4:
There is very useful information that is clearly reported in graphic and Excel formats.

Reviewer 5:
Progress is on track and some insightful results have been produced.

Reviewer 6:
Project progress has sufficiently been made as measured against performance indicators.

Reviewer 7:
The research feeds into work that DOE is funding in multiple ways, both with regards to EV trends as well as potential impacts on overall vehicle efficiency and emissions.

Reviewer 8:
The project appears to make solid progress.

Reviewer 9:
Project accomplishments indicate substantial progress toward addressing the technical barriers by meeting the project deliverables. The team is providing quality data and is writing a report for and providing other insights to VTO. That said, the presentation claims that ANL provides monthly sales reports, but the ANL website says, “As of November 2019, Argonne will release e-drive sales by make and model at the beginning of each quarter.” The project team should adjust its messaging to align with this because it does not provide monthly sales data anymore.

Reviewer 10:
The reviewer indicated no further comments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There are a minimal number of collaborators.

Reviewer 2:
Collaboration appears to be adequate.

Reviewer 3:
The collaboration efforts seem reasonable for gathering EV data; however, the team may need to develop additional collaborative efforts to collect and analyze a variety of new mobility data.

Reviewer 4:

Collaborations with other DOE offices seem good, and there seems to be an open path with other data aggregation activities within the Vehicle Analysis (VAN) program. One challenge highlighted is that the data format and quality of EPA test cycle data- which could potentially be improved with more collaboration- would reduce the burden on data collection within this program, which will be important as the number of available EV models increases.

Reviewer 5:

This was a relatively small project—and could certainly do fine without much collaboration—but now it is larger and doing more in-depth analysis. Getting input on vehicle efficiency metrics and other assumptions, perhaps from industry (OEMs or micromobility operators), would provide validation for vehicle efficiency data and metric development, and perhaps enable the PI and team to acquire more data on scooters and bikes.

Reviewer 6:

Collaboration is only between ANL and ORNL. The team is encouraged to consider discussions with OEMs and dataset users on how best to continue serving them. Getting feedback through a survey will enable the team to understand which stakeholders can serve as partners in this effort.

Reviewer 7:

There is good collaboration with ANL and ORNL, but the reviewer encourages continued or increased collaboration with industry, particularly to get a view of future technology trends in evolving markets and applications, and planned new product introductions (e.g., LD, MD and HD).

Reviewer 8:

There is good collaboration with DOE labs, especially good communication and coordination with ORNL. It will be beneficial to further strengthen public facing documents and data sharing.

Reviewer 9:

The project team should be expanded, in particular to non-VTO end users. To improve the greater societal benefits of this project, the team should incorporate more feedback to the design and analysis from non-VTO end users. The next review should include data utilization metrics such as website page views, citations, and benchmarking against other public market data sources. Improvements should continue to be made over time against these metrics.

Reviewer 10:

No further comments were indicated by this reviewer.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

Continuing to collect, analyze, and publish electrification and new mobility data will provide a valuable resource for inputs to DOE and other researchers’ modeling and analyses. The addition of the plug-in electric vehicle (PEV) model adoption and new mobility technology utilization at the state or regional level would be particularly useful if source data is available.

Reviewer 2:

The project proposes future research that continues current data collection and analysis results dissemination and expands the analysis to include regional electrification impacts. The former are logical next steps for the work, while the latter is a logical expansion.

Reviewer 3:
Proposed research is briefly outlined without explicitly defining barriers and risks. It is not clear how the team is going to overcome the barrier and start sharing regional data with a state by state comparison, and what type of new collaborations and data sources will be used to accomplish the team's goals.

Reviewer 4:
The research plan is sound. It would be interesting to include a correlation of changes in sales trends as a function of federal, regional, or local policy or regulatory activity. The reviewer would also like to know which policies have been most effective at stimulating the adoption of new technologies.

Reviewer 5:
The proposed work of continuous data collection and quantification of national and regional impacts of EVs are beneficial to not only DOE projects, but also to industry and the public.

Reviewer 6:
The team could potentially extend the analysis to the state and city level to help policymakers assess the current baseline in respective states and cities.

Reviewer 7:
Future research appears to be reasonable.

Reviewer 8:
Some of the proposed research focuses on regional impacts of vehicle electrification, which seems to overlap with other VAN programs (e.g. the GREET® team is working to improve emissions models to provide regional information). The reviewer would like to know if this project uses that tool and collaboration to provide an overall analysis of the impact of electrification to date based on trends in sales data, and if the team is planning to develop a different model.

Reviewer 9:
The proposed future research should aim higher. All future research is redundant, with numerous data sources in the private sector. Evaluate these resources and benchmark accordingly for work.

Reviewer 10:
No further comments were provided by the reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
Collecting and synthesizing data for electric and new mobility technologies is critical for informing DOE analyses of transportation energy consumption.

Reviewer 2:
The project does a good job of outlining where the current EV market is in terms of sales and technologies, rather than making predictions. Going forward, this data will be important for validating other models related to vehicle adoption.

Reviewer 3:
This project primarily supports one DOE VTO Analysis Program objective, which is creating and maintaining a strong foundation of data. It provides brief analyses offshoots to augment the incoming data, but no large integrated modeling frameworks.

Reviewer 4:
This team effort is very relevant to DOE and VTO data access and distribution objectives. Open access data availability enables further engineering and scientific discovery, and it is very important for researchers and the public to have access to accurate and well-maintained open vehicle sales databases.

Reviewer 5:
This is highly relevant work.

Reviewer 6:
The project supports overall DOE objectives by providing foundational analytical data.

Reviewer 7:
The project covers DOE's research in both environmental and energy modeling, as well as understanding the forces behind market penetration of EVs.

Reviewer 8:
This project provides the data foundation for electrification-related analysis.

Reviewer 9:
The reviewer indicated no further comments.

Reviewer 10:
No further comments were provided by this reviewer.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer says more could be done with this topic (and references other comments about expanding some of the analyses), which would likely require more resources. Some of the other projects had much larger budgets, but this topic seemed just as important and could be expanded with a slightly larger budget.

Reviewer 2:
The resources are sufficient, and the accomplishments are of great importance, recognizing that the authors were able to analyze the state of micromobility and evaluate levels of use through trips and distances data.

Reviewer 3:
The program budget could potentially be increased to broaden the types of EV-related data that are collected.

Reviewer 4:
Funding appears to be sufficient.

Reviewer 5:
The resources are sufficient.

Reviewer 6:
The resources look sufficient at this time. However, difficulties may arise when some data sources discontinue publication or previously free and low-cost data sources start to charge higher prices. In that scenario, investigators may need more budget support.

Reviewer 7:
The PI should incorporate robotic process automation as much as possible for data collection and analysis.

Reviewer 8:
The project team should work to streamline data collection and validation methods to reduce staff time necessary to incorporate an increasing number of available EV models.

Reviewer 9:
The dollars allotted are quite large compared to the amount of analysis being accomplished, regardless of how high quality the analysis is.

Reviewer 10:
The reviewer had no further comments.

Presentation Number: van033
Presentation Title: Transportation Macroeconomic Accounting Models: VISION and Non-Light Duty Energy and Greenhouse Gas (GHG) Emissions Accounting Tool (NEAT)
Principal Investigator: Joann Zhou (Argonne National Laboratory)

Presenter

Joann Zhou, Argonne National Laboratory

Reviewer Sample Size

A total of ten reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 90% of reviewers indicated that the resources were sufficient, 10% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

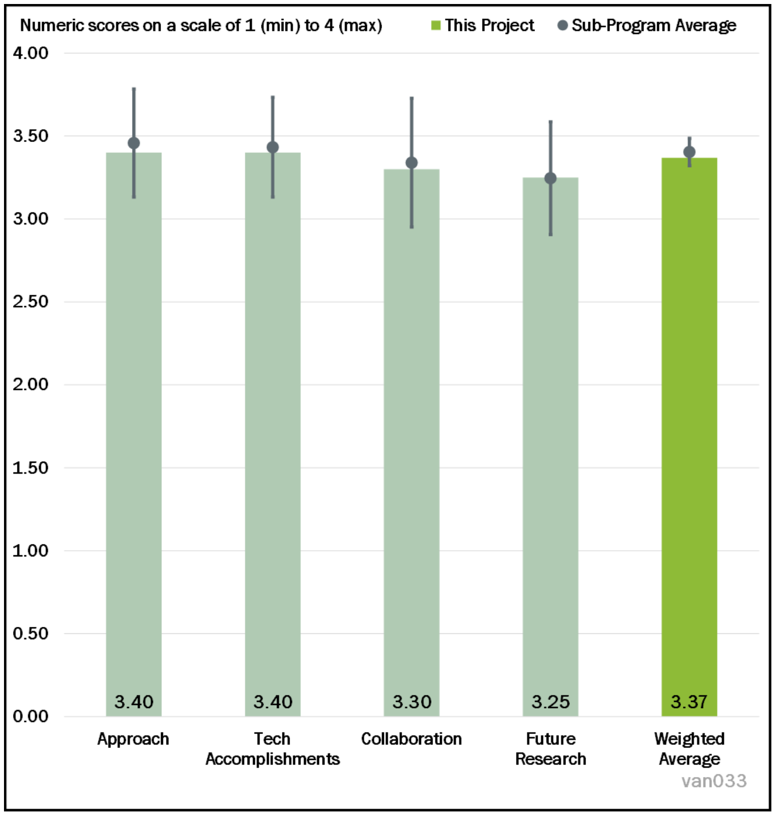

Figure 8-6 - Presentation Number: van033 Presentation Title: Transportation Macroeconomic Accounting Models: VISION and Non-Light Duty Energy and Greenhouse Gas (GHG) Emissions Accounting Tool (NEAT)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The annual updates to calibrate to the AEO and the Freight Analysis Framework (FAF) and update GREET® inputs are worthwhile endeavors. In addition, the planned enhancements in MD and HD modeling capabilities are sensible. Thorough documentation of assumptions and methods will continue to be crucial.

Reviewer 2:

The reviewer liked this modeling effort and is glad to see it is being used by so many other agencies.

Reviewer 3:

The VISION and NEAT updates are performed regularly to keep the models concurrent with the technological changes and provide a robust assessment of energy and emission effects of vehicle deployment scenarios. The annual updates, calibration efforts, as well as the upgrades and the distribution of the platform to the public are well-designed by and feasible for the team working on this project.

Reviewer 4:

Overall, there is a good approach in terms of model maintenance and improvement.

Reviewer 5:

The PI's approach to performing the work appears sound and the project is well designed and feasible.

Reviewer 6:
Annual updates to VISION and NEAT will incorporate market changes and help refine energy use and GHG emissions estimates. Models are critical to the work done on fuel economy standards.

Reviewer 7:
The approach is based on well-established models such as GREET® and FAF.

Reviewer 8:
The barriers are clearly presented. The FY 2020 enhancement plan seeks to better align with emerging technologies. The reviewer would like more of an explanation of which technologies are planned. A reference was made to the DOE MD and HD R&D portfolio which represents good alignment with stakeholders. Further detail would be helpful.

Reviewer 9:
The model provides public facing resources to examine vehicle energy use, although the reliance on other scenarios (e.g. AEO, FAF) does bake in some assumptions that the user cannot account for and adjust.

Reviewer 10:
The technical barriers (see quad chart) are pretty generic (e.g., “difficulty measuring and evaluating energy and emissions impacts of vehicle technologies”). It might be helpful to instead identify barriers from VTO’s most recent MYPP, or perhaps look at the VTO Analysis Program goals and objectives in the most recent Annual Progress Report (APR).

One of the key technical barriers each year for larger modeling frameworks like VISION and NEAT is maintaining and updating inputs, assumptions, and if needed, methodology. The project approach addresses this by utilizing other resources, such as GREET®, for energy and emissions factors and EIA’s AEO for calibration. The approach is feasible, as it has been completed annually for several years. It is also relatively transparent, since the model is publicly available on ANL’s website.

Additionally, the approach includes an enhancement to improve accuracy and usefulness of the projections, namely, dis-aggregating Class 7 and 8 trucks into sleeper, day, and single-unit segments. This addresses the project’s listed barriers by allowing for a more accurate assessment of HD vehicle energy and emissions, since EPA and NHTSA regulations are disaggregated in this fashion. It is also feasible, since data is available (e.g., Polk, EPA, NHTSA).

It would be helpful to know how much the correction factors improved due to the above disaggregation. Hopefully, the PI presents the improvement in those factors when it is available.

It is difficult to see what role the VISION and NEAT modeling framework plays in the DOE VTO suite of models. TRUCK, HDStock, ADOPT, and Market Acceptable of Advanced Automotive Technologies (MA3T) all appear to be more advanced and further along in development. The reviewer would like to know if VISION and NEAT is intended to be more of a tool that stakeholders can “turn knobs” in an online interface to assess impacts of different variables and assumptions.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The updates and annual calibrations are on track. Vision-online is also a useful addition.

Reviewer 2:
The full model is available for download, and although there is a website version, the reviewer periodically had difficulty accessing it.

Reviewer 3:
Accomplishments are tied to the VTO usage of the models (more than 400 users). It is evident how the project was able to meet performance indicators and enable analysis for SMART Mobility teams (e.g., platooning energy savings evaluation and freight electrification potentials).

Reviewer 4:
Models are released to public and the reviewer is looking forward to utilizing them.

Reviewer 5:
Some additional modeling capabilities and granularity have been added to the VISION model which is desirable.

Reviewer 6:
The PI has made clear progress on updating the model in FY 2019 and 2020, in particular with new VISION-online now available to improve end user experience.

The PI notes that the results of the project are used "extensively by DOE programs and other agencies," and includes an absolute number of users. Future merit evaluations should include user data over time and potentially benchmarking against other publicly available models.

Reviewer 7:
Vision-online will be a useful tool for usability. One thing to consider is whether these tools can be used to improve the AEO 2020 reference case for EVs.

Reviewer 8:
The project is making solid progress.

Reviewer 9:
The team appears to have updated the model's historical data (sales, miles per gallon [MPG], stock, VMT, fuel prices, etc.) and energy/emissions intensities from GREET®, and has calibrated the output to EIA's AEO. That said, it is not clear how well the model performs. If the correction factors are large, then the model is not really doing much aside from running in the background and then publishing AEO energy numbers.

The team also appears to have made progress toward disaggregating Class 7 and 8 trucks into 3, rather than 2, segments. It is not clear how far along the team is, but NREL (on the partner list) has considerable experience doing this.

Reviewer 10:
The reviewer indicated no further comments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project has key partners to incorporate broader modeling efforts (e.g., NEMS) and accurate vehicle stock.

Reviewer 2:
ANL appears to be collaborating well with both NREL (expert on MD and HD vehicle benefits analysis and modeling) and ORNL (expert on data availability, identification, and acquisition).

Reviewer 3:
The reviewer observed very good collaborations among DOE laboratories.

Reviewer 4:
Collaboration appears to be adequate.

Reviewer 5:
Coordination with NREL appears to be solid. More end-user feedback to inform future priority work could be helpful.

Reviewer 6:
While the collaboration approach looks reasonable, it may make sense to host a user feedback session to help identify any issues and develop a list of potential new features and flexibilities. Since VISION and TEAM is a mature model, it may be helpful to engage with users to evaluate whether any major or minor changes should be considered.

Reviewer 7:
Collaboration between National Laboratories is well-established, but more information needs to be provided with respect to seamless data integration efforts between laboratories. For example, the reviewer would like to know if the baseline data shared through ORNL and NREL is updated annually.

Reviewer 8:
Comments made on Slide 8 are referring to the need for more data. The need includes annual usage, miles driven, usage profiles, vehicle scrappage, turnover rate, vehicle sector, application and vehicle type, etc. The reviewer presumed this data is available from other DOE and partner resources and that this is not a barrier to planned progress.

Reviewer 9:
NREL seems to carry the majority of the analytical burden for this project. Responsibilities could be better divided.

Reviewer 10:
No further comments were provided by this reviewer.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:
The addition of flexible inputs for new mobility patterns such as annual and lifetime VMT and scrappage rates will be excellent additions. As more data become available on a regional level, a longer-term goal could be to provide regional flexibility.

Reviewer 2:
Continuing to increase the number of MD and HD vehicles included in the model will be helpful. While it is interesting to increase the variables that users can manipulate within scenarios, would they still ultimately be reliant on NEMS scenarios (with different specified conditions)?

Reviewer 3:
Basically, the future research (beyond continuing work in the current FY 2020 and FY 2021 goals) is to make the modeling framework more flexible and usable for a wider range of stakeholders. This seems like it could be a valuable tool, particularly compared to the larger and less easily usable DOE VTO Analysis modeling frameworks.

Reviewer 4:
The reviewer appreciated plans for heterogeneity enhancement and allowance of users to generate scenarios.

Reviewer 5:
The PI has identified valuable heterogeneity enhancements that should be undertaken to maintain the model's value and relevancy.

Reviewer 6:
Additional thoughts on refining the LD component of VISION and NEAT would be interesting.

Reviewer 7:
The team has a great challenge to integrate MD and HD vehicles in the platform and enhance modeling capabilities. More information should be provided with respect to data availability and unavailability of truck data, and how the team is expected to overcome this barrier.

Reviewer 8:
The future work plan is clear and reasonable. This might be out of the control of the investigators of this particular project, but lack of more up to date VIUS data looks to be a concern in the long term for such modeling work, and DOE and other relevant agencies should think of ways to address this issue. It will be beneficial to continue improving the model documentation and public facing sharing.

Reviewer 9:
Future research appears to be reasonable.

Reviewer 10:
The reviewer indicated no further comments.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
VISION and NEAT are beneficial macroeconomic modeling tools for quickly estimating energy and emission impacts of vehicle and fuel systems scenarios.

Reviewer 2:
The model does a good job of (indirectly) incorporating many potential policy or other societal changes that would impact transportation demand, although details about specific technologies and improvements are more limited than other models.

Reviewer 3:
This project specifically addresses the goals of the VTO Analysis Program as follows: assisting VTO in prioritizing technology investments and inform research portfolio planning; supporting the quantitative assessment of vehicle and mobility technology impacts; and providing insight into transportation and energy use problems for a broad range of internal and external stakeholders. The project does this by supporting one of the broader objectives, which is to build, maintain, and exercise relevant analytical models.

Reviewer 4:
The project helps create the universe of public models to estimate GHG and energy that stakeholders can use to analyze these elements from vehicle technologies.

Reviewer 5:
Tools to increase the understanding of MD and HD vehicles are in dire need.

Reviewer 6:
The work is very relevant to DOE objectives like enhancing tools that estimate GHG emissions and energy use of alternate vehicle technologies with macroeconomic approaches.

Reviewer 7:
The project supports overall DOE objectives by providing core analytical tools.

Reviewer 8:
The project helps create the universe of public models to estimate GHG and energy that stakeholders can use to analyze these elements from vehicle technologies.

Reviewer 9:
The work is relevant.

Reviewer 10:
The reviewer indicated no further comments.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Given the importance of these models to the research community, the project could benefit from additional funding to address any major outstanding issues or additional research ideas.

Reviewer 2:
The resources are sufficient for the project to achieve milestones in timely fashion.

Reviewer 3:
There is no FY 2020 budget described in the slides, but the work appears to be progressing.

Reviewer 4:
The funding is sufficient.

Reviewer 5:
The resources look sufficient at this time.

Reviewer 6:
Increased resources for FY 2019 were in line with the objectives for launching a web version of the model, which may not need to continue at the same level.

Reviewer 7:
The resources at the team's disposal are sufficient to achieve the project's milestones. A clearer understanding of the data updates and integration across National Laboratories would be useful to demonstrate success of resources integration.

Reviewer 8:
The resources should be sufficient given that NREL and ORNL stay on to provide assistance. It is hard to imagine that the PI—who is a team lead at ANL—has time to do much of the work on both this project and the LD vehicle and EV Sales Analysis project.

Reviewer 9:
No further comments were provided by this reviewer.

Reviewer 10:
The reviewer indicated no further comments.

Acronyms and Abbreviations

ADOPT	Automotive Deployment Options Projects Tool
AEO	Annual Energy Outlook
AFDC	Alternative Fuels Data Center
AFI	Alternative fuel infrastructure
AFV	Alternative fuel vehicle
ANL	Argonne National Laboratory
APR	Annual Progress Report
AV	Autonomous vehicle
BETO	Bioenergy Technologies Office
BEV	Battery electric vehicle
C2G	Cradle-to-grave
CAV	Connected and autonomous vehicle
CV	Connected vehicle
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EEMS	Energy Efficient Mobility Systems
EIA	Energy Information Administration
EPA	U.S. Environmental Protection Agency
EV	Electric vehicle
FAF	Freight Analysis Framework
FOTW	Fact of the Week
GHG	Greenhouse gas
GREET®	Greenhouse gas, Regulated Emissions, and Energy use in Transportation
H_2	Hydrogen
HD	Heavy-duty
HEV	Hybrid electric vehicle
HFTO	Hydrogen and Fuel Cells Technologies Office
HPC	High performance computing

ICE	Internal combustion engine
LCA	Life-cycle analysis
LD	Light-duty
LDV	Light-duty vehicle
MD	Medium-duty
M/HDV	Medium- and heavy-duty vehicle
MYPP	Multi-Year Program Plan
NEAT	Non-light duty Energy and greenhouse gas emissions Accounting Tool
NEMS	National Energy Modeling System
NHTSA	National Highway Traffic Safety Administration
NREL	National Renewable Energy Laboratory
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PHEV	Plug-in hybrid electric vehicle
PI	Principal Investigator
Q	Quarter
R&D	Research and development
RD&D	Research, development, and demonstration
SMART	Systems and Modeling for Accelerated Research in Transportation
TCO	Total cost of ownership
TEBD	Transportation Energy Data Book
TNC	Transportation network company
U.S.	United States
U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability
VAN	VTO Analysis
VIUS	Vehicle Inventory and Use Survey
VMT	Vehicle-miles traveled
VTO	Vehicle Technologies Office

9. Acronyms and Abbreviations

°C	Degrees Celsius
µ DIC	Microscopic level DIC
µL	Microliter
0-D	Zero-dimensional
100LL	100 low lead
12Cr	12% chromium by weight
1-D	One-dimensional
21CTP	21st Century Truck Partnership
2-D	Two-dimensional
3-D	Three-dimensional
4X	4X Technologies
A/F	Air-fuel ratio
A/F	Amplitude-frequency
A356	356 aluminum
ABL	Acrylonitrile butadiene lignin
AC	alternating current
ACC	Adaptive cruise control
ACE	Advanced Combustion Engine
ACEC	Advanced Combustion and Emissions Control
ACES	Automated, connected, electric and/or shared
ACI	Advanced compression ignition
ACM	American Center for Mobility
ACP	Advanced Carbon Products
ADOPT	Automotive Deployment Options Projects Tool
AEC	Advanced Engine Combustion
AEO	Annual Energy Outlook
AEV	Autonomous electric vehicle

AFA	Alumina-forming austenitic
AFC	Alternative Fuel Corridor
AFDC	Alternative Fuels Data Center
AFI	Advanced Fueling Infrastructure
AFI	Alternative fuel infrastructure
AFIDA	Advanced fuel ignition delay analyzer
AFM	Atomic force microscopy
AFV	Alternative fuel vehicle
AGC	Aluminum graphene composite
Ah	Ampere-hour (amp-hour)
AI	Artificial intelligence
AIMSUN	Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks
AKI	Anti-knock index
Al	Aluminum
$Al_{10}SiMg$	Aluminum-silicon-magnesium
Al_2Cu	Aluminum-copper
Al_2O_3	Aluminum oxide (alumina)
ALD	Atomic-layer deposition
ALS	Advanced Light Source
AM	Additive manufacturing
AMBER	Advanced Model Based Engineering Resource
AMC	Aluminum matrix composite
AMD	Automated Mobility District
AMFI	Additive-mixing fuel injection
AMR	Annual Merit Review
ANL	Argonne National Laboratory
API	Application programming interface
APR	Annual Progress Report

APS	Atmospheric Plasma Solutions
APS	Advanced Photon Source
APT	Atom probe tomography
AR	Augmented reality
ARB	Air Resources Board
ARPA-E	Advanced Research Projects Agency - Energy
ASM	American Society for Metals
ATF	Automatic transmission fluid
ATHENA	Advanced Transportation Hub Efficiency using Novel Analysis
ATM	Active traffic management
AV	Autonomous vehicle; Automated vehicle
AZ31B	Aluminum and zinc magnesium alloy
B	Magnetic flux density
$BaTiO_2$	Barium titanate
BAU	Business as usual
BEA	Zeolite beta
BEAM	Behavior, Energy, Autonomy, and Mobility
BETO	Bioenergy Technologies Office
BEV	Battery electric vehicle
Bi	Bismuth
Bio-ACN	Bio-acrylonitrile
BMEP	Brake-mean effective pressure
BMR	Battery Materials Research Program
BNL	Brookhaven National Laboratory
BOB	Blendstocks for oxygenate blending
BOMA	Building Owners and Managers Association
BP	Budget period
BRT	Bus rapid transit

BSFC	Brake-specific fuel consumption
C	Carbon
C2G	Cradle-to-grave
Ca	Calcium
CA50	Crank angle at 50% mass fraction burned
CACC	Cooperative adaptive cruise control; coordinated adaptive cruise control
CAD	Computer aided design
CADES	Compute and Data Environment for Science
CADS	Cyber anomaly detection system
CAE	Computer-aided engineering
CaF_2	Calcium fluoride
CALPH	CALculation of PHAse Diagrams
CAM	Cathode active material
CARB	California Air Resources Board
CARLA	Computer-Assisted Related Language Adaptation
CAV	Connected and autonomous vehicle
CB	Cell build
CB	Custom blend
CC	Constant current
CC	Cruise control
CC	Clean Cities
CCE	Closed-cycle efficiency
CCV	Closed-crankcase ventilation
Cd	Coefficient of drag
CDC	Change-data capture
CDC	Conventional diesel combustion
CDTI	Clean Diesel Technology, Inc.
Ce	Cerium

CE	Coulombic efficiency
CEI	Cathode-electrolyte interphase
CeO_2	Cerium oxide (ceria)
CF	Carbon fiber
CFD	Computational fluid dynamics
CFM	Composite framework materials
CFR	Cooperative fuel research
CFRC	Carbon fiber reinforced composites
CFRP	Carbon fiber-reinforced polymer
CFTF	Carbon Fiber Technology Facility
CH_4	Methane
CHT	Conjugate heat transfer
CI	Compression ignition
CLEERS	Crosscut Lean Exhaust Emissions Reduction Simulations
CLi-P-SCP	Conjugated Li-polymer S- containing polymer
cm	Centimeter
CMOS	Complementary-symmetry metal
CN	Cetane number
CNG	Compressed natural gas
CNT	Carbon nanotube
Co	Cobalt
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2-AP	CO_2-atmospheric plasma
COTS	Commercial off-the-shelf
COV	Coefficient of variation
CPEC	Close proximity electromagnetic carbonization
CPU	Central processing unit

CR	Compression ratio
Cr_2O_3	Chromium (III) oxide
CRADA	Cooperative research and development agreement
CRC	Coordinating Research Council
CRM	Coordinated ramp metering
C_{rr}	Coefficient of rolling resistance
CRS	Cold-rolled steel
CT	Computerized tomography
CTA	Chicago Transit Authority
CTE	Coefficient of thermal expansion
CTI	Cleaner Truck Initiative
CTP	Coal tar pitch
Cu	Copper
CV	Connected vehicle
DARPA	Defense Advanced Research Projects Agency
DBC	Direct bonded copper
DC	Direct current
DCFC	Direct-current fast charging
DCIR	Direct current internal resistance
DCR	Discharge capacity rate
DEF	Diesel exhaust fluid
DEMS	Differential electrochemical mass spectroscopy
DER	Distributed energy resources
DFI	Ducted fuel injection
DFT	Density functional theory
DFW	Dallas-Fort Worth International Airport
DIC	Digital image correlation
DISI	Direct-injection spark ignition

DNS	Direct numerical simulations
DOC	Diesel oxidation catalyst
DoD	Department of Defense
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DPF	Diesel particulate filter
DPWT	Dynamic wireless power transfer
DRIFTS	Diffuse reflectance infrared Fourier-transform spectroscopy
DRX	Cation-disordered rock salt
DSS	Distribution System Simulator
DST	Dynamic stress test
DTG	data.transportation.gov
DTNA	Daimler Trucks North America LLC
DWPT	Dynamic Wireless Power Transfer
Dy	Dysprosium
E10	10% ethanol content gasoline
E15	Gasoline blended with 10.5%-15% ethanol
EAD	Eco-approach and departure
EAM	Electrochemically active monolayer
EC	Electrochemical (electronic) conducting
ECFM	Extended coherent flame model
ECN	Engine Combustion Network
eco-CAC	Eco-cooperated automated control
e-commerce	Electronic commerce
ECU	Engine control unit
EDS	Energy-dispersive X-ray spectroscopy
EDX	Energy-dispersive X-ray
EELS	Electron energy loss spectroscopy

EEMS	Energy Efficient Mobility Systems
EERE	Energy Efficiency and Renewable Energy
EETT	Electrical and Electronics Technical Team
EG	Electrogalvanized
EGR	Exhaust gas recirculation
EHN	2-ethylhexyl nitrate
EIA	Energy Information Administration
EIS	Electrochemical impedance spectroscopy
ELT	Electrification Technologies
EM	Electron microscopy
EMG	E-Mobility Group
EMI	Electromagnetic interference
EMS	Energy management system
EMSL	Environmental Molecular Science Laboratory
EOL	End of life
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
e-scooter	Electric scooter
ESS	Energy storage system
ETEM	Environmental transmission electron microscopy
EV	Electric vehicle
EVSE	Electric vehicle service equipment
FAF	Freight Analysis Framework
FC	Fast charge
FCA	Fiat-Chrysler Automobiles
FCE	First-cycle efficiency
FCML	Flying Capacitor Multilevel
FE	Fuel economy

FE	Fuel efficiency
Fe	Iron
FE	Finite element
Fe_4N	Iron nitride
FEA	Finite element analysis
FEAD	Front-end accessory drive
FEC	Fluoroethylene carbonate
FeCo	Iron-cobalt
FedEx	Federal Express
FHWA	Federal Highway Administration
F-MEP	Freight mobility energy productivity
FMLM	First-mile and last-mile
FOA	Funding Opportunity Announcement
FOTW	Fact of the Week
FSE	Friction stir extrusion
FSP	Flame-spray pyrolysis
FSP	Friction stir processing
FSW	Friction stir welding
FTIR	Fourier-transform infrared
FTP	Federal Test Procedure
FWC	Four-way catalyst
FY	Fiscal year
g	Gram
GaN	Gallium nitride
GAO	Genetic algorithm optimization
GCI	Gasoline compression ignition
GCMS	Gas chromatography mass spectroscopy
GDCI	Gasoline direct injection compression ignition

GDI	Gasoline direct injection
GEM	Greenhouse gas Emissions Model
Georgia Tech	Georgia Institute of Technology
GHG	Greenhouse gas
GISAXS	Grazing incidence small-angle X-ray scattering
GITT	Grid integration technical team
GM	General Motors
Go	Graphene oxide
GPF	Gasoline particulate filter
GPS	Global positioning system
GPU	Graphics processing unit
GREET®	Greenhouse gas, Regulated Emissions, and Energy use in Transportation
GUI	Graphical user interface
GVW	Gross vehicle weight
GVWR	Gross vehicle weight rating
H	Hydrogen
H	Magnetic field strength
H_2	Hydrogen
H2D2	Heavy-duty hybrid diesel
H_2O	Water
HAADF-STEM	High annular dark field scanning transmission electron microscopy
HALT	Highly accelerated lifetime test
HATCI	Hyundai Kia America Test Center
HC	Hydrocarbon
HCCI	Homogeneous charge compression ignition
HCEs	High consequence events
HCF	High-cycle fatigue
HCT	Hydrocarbon trap

HD	Heavy-duty
HDD	Heavy duty diesel
HEDM	High-energy diffraction microscopy
HELICS	Hierarchical Engine for Large-scale Infrastructure Co-Simulation
HEMT	High-electron-mobility transistor
HEV	Hybrid electric vehicle
HF	Hydrofluoric acid
HFTO	Hydrogen and Fuel Cells Technologies Office
HIL	Hardware-in-the-loop
HNCO	Isocyanic acid
HOLE	Highly ordered laser-patterned electrode
HOMO	Highest occupied molecular orbit
HOV	Heat of vaporization
HP	Horsepower
HPC	High performance computing
HPF	High-performance fuels
HP-RTM	High-pressure resin transfer molding
HRE	Heavy rare earth
HRM	Homogeneous relaxation model
HSFW	High-speed flywheel
HSS	High-strength steel
HT	High temperature
HTA	Hydrothermally aged
HVAC	Heating, ventilating, and air conditioning
Hz	Hertz
IACMI	Institute for Advanced Composites Manufacturing Innovation
IACS	International Annealed Copper Standard
IC	Internal combustion

ICE	Internal combustion engine
ICL	Irreversible capacity loss
ICME	Integrated computational materials engineering
ID	Ignition delay
IDOT	Illinois Department of Transportation
IDZ	Interdiffusion zone
IEEE	Institute of Electrical and Electronics Engineers
iHOV	Instantaneous heat of vaporization
IIC	Indiana Integrated Circuits
ILSS	Interlaminar shear strength
IMEP	Indicated mean effective pressure
IMS	Insulated metal substrate
INL	Idaho National Laboratory
IP	Intellectual property
IPM	Interior permanent magnet
ISFC	Indicated specific fuel consumption
IT	Information technology
JBS	Junction barrier Schottky
JES	*Journal of the Electrochemical Society*
JM	Johnson Matthey
JRC	Joint Research Center
K	Potassium
K	Empirical factor (or constant)
kg	Kilogram
kp	Parabolic rate constant
ksi	Kilopound per square inch
kW	Kilowatt
kWh	Kilowatt hours

KWN	Kampmann-Wagner
L	Liter
L2	Level 2
LANL	Los Alamos National Laboratory
LATP	Lithium aluminum titanium phosphate
lb	Pound
LBNL	Lawrence Berkeley National Laboratory
LCA	Life-cycle analysis
LCO	Lithium cobalt oxide ($LiCoO_2$)
LD	Light-duty
LDP	LiveWire Data Platform
LDV	Light-duty vehicle
LES	Large eddy simulation
LEV	Low-emission vehicle
LEV III	Low-emission vehicle level III
LFP	Lithium-ion phosphate
LHCE	Localized high-concentration electrolyte
Li	Lithium
Li_2S	Lithium sulfide
LIB	Lithium-ion battery
$LiBO_2$	Lithium borate
LIC	Lithium-ion conducting
LiDFOB	Lithium diofluoro(oxalate) borate
LiEDC	Lithium ethylene dicarbonate
LiF	Lithium fluoride
LiFSI	Lithium bis(fluorosulfonyl)imide
LiPAA	Lithium polyacrylate
$LiPF_6$	Lithium hexafluorophosphate

LiTFSI	Lithium bis(trifluoromethanesulfonyl)imide
LLNL	Lawrence Livermore National Laboratory
LLS	Layered-layered spinel
LLZO	Lithium lanthanum zirconate
LMB	Lithium-metal battery
LMNO	Lithium manganese nickel oxide
LMNOF	Li-Mn-Ni-O-F
LMP	Larson-Miller Parameter
LMR	Lithium-manganese rich
LNCO	Lithium nickel cobalt oxide
LNMO	$LiNi_{0.5}Mn_{1.5}O_2$
LNO	Lithium-nickel dioxide ($LiNiO_2$)
LPBF	Laser powder bed fusion
LRRM	Local responsive ramp metering
LSPI	Low-speed pre-ignition
LT	Low temperature
LTC	Low-temperature combustion
LTGC	Low-temperature gasoline combustion
LTMO	Lithium transition metal oxide
LTNA	Low-temperature NO_x adsorber
LTO	Lithium titanate
LTP	Low-temperature plasma
LUMO	Lowest unoccupied molecular orbit
LW	Livengood-Wu
m	Meter
M	Molarity
M/HDV	Medium- and heavy-duty vehicle
MA	Methyl acetate

mAh	Milliamp-hour
MAS	Micro alloyed steel
MCCI	Mixing-controlled compression ignition
MCE	Multi-cylinder engine
MD	Molecular dynamics
MD	Medium-duty
MDF	Manufacturing Demonstration Facility
MDOT	Michigan Department of Transportation
MENNDL	Multi-node Evolutionary Neural Networks for Deep Learning
MEP	Mobility Energy Productivity
MERF	Materials Engineering Research Facility
Mg	Magnesium
Mg_2SiO_4	Forsterite
$MgCO_3$	Magnesium carbonate
MgO	Magnesium oxide
MGU	Motor-generator unit
MHDV	Medium- and heavy-duty vehicle
Micro-CT	Micro-computed tomography
MIMO	Multi-input and multi-output
min.	Minute
MIT	Massachusetts Institute of Technology
ML	Machine learning
MLPC	Multi-layer pouch cell
mm	Millimeter
MM	Multi-mode
MMC	Metal-matrix composites
MMIFE	Multi-modal intercity freight energy
Mn	Manganese

MnBi	Manganese bismuth
$MnCO_3$	Manganese carbonate
MOD	Mobility-on-demand
MON	Motor octane number
MOSFET	Metal oxide semiconductor field effect transistor
MOTIVE	Mobility and Technology Insight Validation Evidence
MOU	Memorandum of understanding
MPa	Megapascals
MPGe	Miles per gallon equivalent
mph	Miles per hour
MPO	Metropolitan Planning Organization
Msi	Million pounds per square inch
MTC	Metropolitan Transportation Commission
MUD	Multi-unit dwelling
mV	Millivolt
MV	Medium Voltage
MW+	Megawatt plus
MY	Model year
MYPP	Multi-Year Program Plan
N/P	Negative-positive ratio
N_2O	Nitrous oxide
NA	North America
NACFE	North American Council for Freight Efficiency
Nb	Niobium
NCA	Nickel cobalt aluminum oxide
NCE	No-cost extension
NCM	Nickel cobalt manganese oxide
NDA	Non-disclosure agreement

NdFeB	Neodymium iron boron
NEAT	Non-light duty Energy and greenhouse gas emissions Accounting Tool
NEMS	National Energy Modeling System
NERVE	Networked Elements for Resin Visualization and Evaluation
NEXTCAR	Next-Generation Energy Technologies for Connected and Automated On-Road Vehicles
NFA	Nanostructured ferritic alloy
NG	Natural gas
NGO	Non-governmental organizations
NGV	Natural gas vehicle
NH_3	Ammonia
NHTSA	National Highway Traffic Safety Administration
Ni	Nickel
NIC	Network interface card
NiCr	Nichrome
NMA	Nickel manganese aluminum
NMC	Nickel manganese cobalt oxide
NMCA	Nickel manganese cobalt aluminum
NMFTA	National Motor Freight Traffic Association, Inc.
NMP	N-methyl-2-pyrrolidone
NMR	Nuclear magnetic resonance
NN	Neural network
NO	Nitric oxide (nitrogen monoxide)
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
NP	Nano-palladium
NREL	National Renewable Energy Laboratory
NREL80	80-mile work day duty cycle developed by NREL
NTC	Negative-temperature coefficient

O_2	Oxygen
OBD	On-board diagnostics
OC	Oxidation catalyst
OCE	Open-cycle efficiency
ODBC	Organic film based direct bonded copper
OEM	Original equipment manufacturer
OEMS	Online electrochemical mass spectroscopy
OI	Octane index
OIM	Organic insertion material
ORNL	Oak Ridge National Laboratory
OS	Octane sensitivity
OSC	Oxygen storage capacity/component
OSU	Ohio State University
P	Phosphorous
PACE	Partnership for Advanced Combustion Engines
PAH	Polycyclic aromatic hydrocarbon
PAN	Polyacrylonitrile
PC	Pre-chamber
PCC	Predictive cruise control
Pd	Palladium
PDF	Pair-distribution function
PEO	Polyethylene oxide
PEV	Plug-in electric vehicle
PF	Phase field
PFI	Port fuel injection
PFS	Partial fuel stratification
PG&E	Pacific Gas & Electric
PGM	Platinum group metals

PHEV	Plug-in hybrid electric vehicle
PI	Principal Investigator
PIONA	Paraffins, iso-paraffins, olefins, naphthenes, and aromatics
PKI	Public key infrastructure
PM	Particulate matter
PM	Permanent magnet
PMCP	Powertrain Materials Core Program
PMI	Particulate matter index
PN	Particle number
PNA	Passive NO_x adsorber
PNNL	Pacific Northwest National Laboratory
POE	Power over ethernet
POLARIS	Planning and Operations Language for Agent-based Regional Integrated Simulation
POP	unknown acronym
PP	Polypropylene
PPCI	Partially pre-mixed compression ignition
ppm	Parts per million
PS	Polysulfide
PSD	Pore-size distribution
psi	Pounds per square inch
PSU	Penn State University
Pt	Platinum
P-T	Pressure-temperature
PTO	Pyrene-4,5,9,10-tetraone
PU	Per unit
PV	Photovoltaic
PVDF	Polyvinylidene difluoride
PWM	Pulse width modulation

PμSL	microstereolithography
Q	Quarter
Q&A	Question and answer
QDTA	Quasi-dynamic traffic assignment
R value	Resistance to heat flow
R&D	Research and development
R2R	Roll-to-roll
Ra	Roughness average
RANS	Reynolds-averaged Navier-Stokes
RCM	Rapid compression machine
RD&D	Research, development, and demonstration
RE	Rare earth
ReaxFF	Reactive force field
REE	Rare earth element
RFP	Request for proposals
Rh	Rhodium
RIM	Reaction Injection Molding
RM	Ramp metering
RMS	Root mean square
ROI	Return on investment
RON	Research octane number
RPC	Reactive-polymer composite
RST	Reactive-spray technology
RSW	Resistance spot weld
RT	Room temperature
RTM	Resin transfer molding
s	Second
S	Sulfur

SAC	Single-atom catalyst
SACI	Spark-assisted compression ignition
SAE	Society of Automotive Engineers
SAV	Shared and automated vehicles
SAW	Surface-acoustic wave
SBD	Schottky barrier diode
SBIR	Small Business Innovation Research
SCAQMD	South Coast Air Quality Management District
SCE	Single-cylinder engine
SCO	Selective catalytic oxidation
SCR	Selective catalytic reduction
SCRF	Selective catalytic reduction on filter
SDOs	Standards developing organizations
SECCM	Scanning electrochemical cell microscopy
SEED	Seeking Educational Equity and Diversity
SEI	Silicon electrolyte interface
SEI	Solid electrolyte interphase
SEISTA	Silicon electrolyte interface stability
SEM	Scanning electron microscope
SERS	Surface-enhanced Raman spectroscopy
SFCTA	San Francisco County Transportation Authority
ShAPE™	Shear Assisted Processing and Extrusion
Si	Silicon
SI	Spark ignition
SiC	Silicon carbide
SIL	Software-in-the-loop
SIMS	Secondary ion mass spectroscopy
SiO_x	Silicon Oxides

SLAC	Stanford Linear Accelerator Center
SMART	Systems and Modeling for Accelerated Research in Transportation
SMC	Soft magnetic composites
Sn	Tin
SNL	Sandia National Laboratories
SNS	Spallation Neutron Source
SOA	State of the art
SOC	State of charge
SOI	Start of injection
SON	Supercharged octane number
SOPO	Statement of Project Objectives
SOW	Statement of work
SP	Solution process
Spaci-MS	Spatially resolved capillary inlet - mass spectroscopy
SPAN	Sulfurized polyacrylonitrile
SPI	Stochastic pre-ignition
SPIN	Smart Power Integrated Node
SPM	Surface permanent magnet
SPR	Self-pierce rivet
SPS	Single-prolonged stress
SRI	Southern Research Institute
SSE	Solid-state electrolyte
SStAC	Stainless steel alloy corrosion
SSZ	Alumina silicate zeolite
ST2	SuperTruck 2
STEM	Scanning transmission electron microscopy
STRIDE	Spoofing, tampering, repudiation, information disclosure, denial of service, elevation of privilege
STTR	Small Business Technology Transfer

SULEV	Super ultra-low emissions vehicle
$SULEV_{30}$	Super ultra-low emissions vehicle with 0.030 grams/mile combined non-methane organic gases and NO_x
SUNY Poly	State University of New York Polytechnic
SuRF	Scale-up Research Facility
SwRI	Southwest Research Institute
T	Temperature
T6	Temper 6
T50	Temperature at which 50% of the distillate fuel is recovered in a distillation experiment
T90	Temperature at which 90% of the distillate fuel is recovered in a distillation experiment
TCO	Total cost of ownership
TCR	Temperature coefficient of resistance
TDC	Top dead center
TEAD	Transportation Energy Analysis Dashboard
TEBD	Transportation Energy Data Book
Tech	Technical
TEM	Transmission electron microscopy
Tg	Glass transition temperature
THD	Total harmonic distortion
Ti	Titanium
TiB_2	Titanium diboride
TiO_2	Titanium dioxide
TJI	Turbulent jet ignition
TL	Trifunctional linker
TLP	Transient liquid phase
TM	Transition metal
TNC	Transportation network company
TNO	Titanium niobium oxide

TPG	Thermal pyrolytic graphite
TPO	Transportation Planning Organizations
TRL	Technology readiness level
TTE	1,1,2,2-tetrafluoroethyl-2,2,3,3-tetrafluoropropyl ether
TuFF	Tailored universal Feedstock for Forming
TWC	Three-way catalyst
U.S.	United States
U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability
UCLA	University of California, Los Angeles
UCSB	University of California at Santa Barbara
UD	University of Delaware
UHC	Unburned hydrocarbons
ULNO$_x$	Ultra-low NO$_x$
µm	Micrometer
UM	University of Michigan
UMEI	University of Michigan Energy Institute
UNCC	University of North Carolina at Charlotte
UPS	United Parcel Service
UrbanSim	Urban Simulation
URI	University of Rhode Island
USCAR	United States Council for Automotive Research
USPS	United States Postal Service
USW	Ultrasonic welding
UT-Austin	University of Texas at Austin
UTK	University of Tennessee, Knoxville
UTS	Ultimate tensile strength
UVA	University of Virginia
UW	University of Wyoming

V	Volt
V2G	Vehicle-to-Grid
V2V	Vehicle to vehicle
V2X	Vehicle-to-anything
VAN	VTO Analysis
VAR	Vacuum arc re-melting
VDC	Volts of direct current
VIL	Vehicle-in-the-loop
VIM	Vacuum induction molding
Virginia Tech	Virginia Polytechnic Institute
VIUS	Vehicle Inventory and Use Survey
VMT	Vehicle-miles traveled
VOTT	Value of travel time
VSA	Variable speed advisory
VT	Virginia Polytechnic and State University
VTO	Vehicle Technologies Office
WBG	Wide bandgap
WECC	Western Interconnection model
Wh/kg	Watt-hour per kilogram
WPI	Worcester Polytechnic Institute
WRI	Western Research Institute
wt. %	Weight percent
WTW	Well-to-wheels
WXFC	Wireless extreme fast charging
XFC	Extreme fast charging
XPS	X-ray photoelectron spectroscopy
XRD	X-ray diffraction
Y	Yield-sooting index

YS	Yield strength
ZANZEFF	Zero and Near-Zero Emissions Freight Facilities
ZECT II	Zero-Emission Cargo Transport II
Zero-RK	Zero-order Reaction Kinetics
Zn	Zinc
ZnPhos	Zinc phosphating
ZrO_x	Zirconium sub-oxide

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