U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

2022 Annual Merit Review, Vehicle Technologies Office

Results Report

November 2022

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Introduction

The 2022 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 21-23, 2022, as a hybrid event with in-person and virtual attendance. The review encompassed work done by VTO: 213 individual activities were reviewed by 255 reviewers. Exactly 1,051 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 three 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, with 4.0 being the highest possible score, by VTO subprogram portfolio are presented below.

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

VTO Subprogram	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Battery R&D (BAT)	3.45	3.38	3.42	3.31	3.39
Decarbonization of Off-Road, Rail, Marine, and Aviation (formerly Advanced Engine and Fuel Technologies	3.27	3.15	3.24	3.12	3.19
Electrification (ELT)	3.33	3.27	3.31	3.22	3.29
Energy Efficient Mobility Systems (EEMS)	3.29	3.36	3.37	3.17	3.32
Materials Technology (MAT)	3.21	3.25	3.24	3.15	3.23
Vehicle Analysis (VAN)	3.64	3.60	3.42	3.43	3.57

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

VTO Subprogram	Objectives	Approach	Accomplish-ments	Collaborations	Equity/ Justice	Weighted Average
Technology Integration (TI)	3.46	3.27	3.13	3.35	3.18	3.25

Evaluation Criteria—Research & Development Subprograms

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: ***Question 1: Approach to performing the work—How would you rate the degree to which technical barriers are addressed? Is the project well designed, and is the timeline reasonably planned? (Scoring weight for overall average = 25%)***

- 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 2: ***Question 2: Technical Accomplishments and Progress—How would you rate the technical progress that has been made compared to the project plan? (Scoring weight for overall average = 50%)***

- 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: *Question 3: Collaboration and Coordination Across Project Team— How would you rate the collaboration within the project team? Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed? (Scoring weight for overall average = 12.5%)*

- 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 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: *Question 4: Proposed Future Research—How would you rate the proposed future research? Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets? (Scoring weight for overall average = 12.5%)*

- 4.0=Outstanding. Purpose of future work and likelihood of achieving future work targets clearly stated.
- 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 5: *Question 5: Relevance—Is the project relevant? Does the project support the overall VTO subprogram objectives? (Did not factor into overall weighted average numeric score)*

- Yes
- No.

Question 6: *Question 6: Resources—How would you rate the resources of the project? Are the resources sufficient for the project to achieve the stated milestones in a timely fashion? Did not factor into overall weighted average numeric score)*

- Excessive
- Sufficient
- Insufficient.

Evaluation Criteria—Technology Integration Subprogram

Reviewers for the Technology Integration (TI) technical session answered questions tailored to TI's 2022 AMR focus on improving fuel diversity, increasing local resiliency, and reducing greenhouse gas emissions. These technical questions are listed below, along with appropriate scoring metrics.

Question 1: ***Question 1. Project Objectives— How would you rate this project's degree of support for the overall Technology Integration (TI) objectives of improving fuel diversity, increasing local resiliency, and reducing greenhouse gas emissions through increasing alternative fuel use and transportation efficiency? (Scoring weight for overall average = 20%)***

- 4.0=Outstanding. Project Objectives are sharply focused on supporting DOE/VTO/TI objectives. 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/TI objectives; project addresses a significant number of barriers; effectively contributes to program objectives.
- 3.0=Good. Project objectives are generally effective and support DOE/VTO/TI objectives but could be improved; project addresses some barriers; contributes to program objectives.
- 2.5=Satisfactory. Project objectives have some weaknesses and support DOE/VTO/TI objectives; project addresses some barriers; project may have some impact in achieving program objectives.
- 2.0=Fair. Project objectives have significant weaknesses and minimally support DOE/VTO/TI objectives; project addresses few barriers; project may have a small impact on achieving program objectives.
- 1.5=Poor. Project objectives are minimally responsive to DOE/VTO/TI objectives; project does not address barriers; project is unlikely to contribute materially to achieving program objectives.
- 1.0=Unsatisfactory. Project objectives are not responsive to DOE/VTO/TI objectives project fails to address any barriers; project is highly unlikely to contribute materially to achieving program objectives.

Question 2: ***Question 2. Project Approach— How would you rate this project's approach for integrating advanced transportation technologies and practices to solve real-world challenges? (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: ***Question 3. Project Accomplishments and Progress— How would you rate the project's progress and significant accomplishments to date? (Scoring weight for overall average = 40%)***

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

Question 4: ***Question 4. Collaboration and Coordination Among Project Team— How would you rate the level of collaboration within the project team and the degree to which the project team has identified and leveraged the proper connections to achieve its project goals? (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 effectively carry out 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 lacks effective working relationships.
- 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: ***Question 5. Energy Equity and Environmental Justice Project Contribution— How would you rate the contribution of this project to energy equity and environmental justice by ensuring the project benefits underserved and overburdened communities and does not cause increased burdens to these communities? (Scoring Weight for overall average = 10%)***

- 4.0=Outstanding. Project maximizes the benefits to underserved and overburdened communities and incorporates affected communities in the planning and execution of the project.
- 3.5=Excellent. Project maximizes the benefits to underserved and overburdened communities and includes some collaboration with affected communities
- 3.0=Good. Project will have significant benefits to underserved and overburdened communities.
- 2.5=Satisfactory. Project will have some benefits to underserved and overburdened communities
- 2.0=Fair. Project does not benefit or burden underserved and overburdened communities.
- 1.5=Poor. Project will have some benefits to underserved and overburdened communities while also causing increased burdens to underserved and overburdened communities.
- 1.0=Unsatisfactory. Project has no benefits to underserved and overburdened communities while also causing increased burdens to underserved and overburdened communities.

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 0.25] + [Question 2 Score x 0.50] +

[Question 3 Score x 0.125] + [Question 4 Score x 0.125]

*R&D subprogram Questions 5 and 6 were not factored in the Weighted Average Score calculation because their scoring scales were incompatible with Questions 1 through 4.

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.

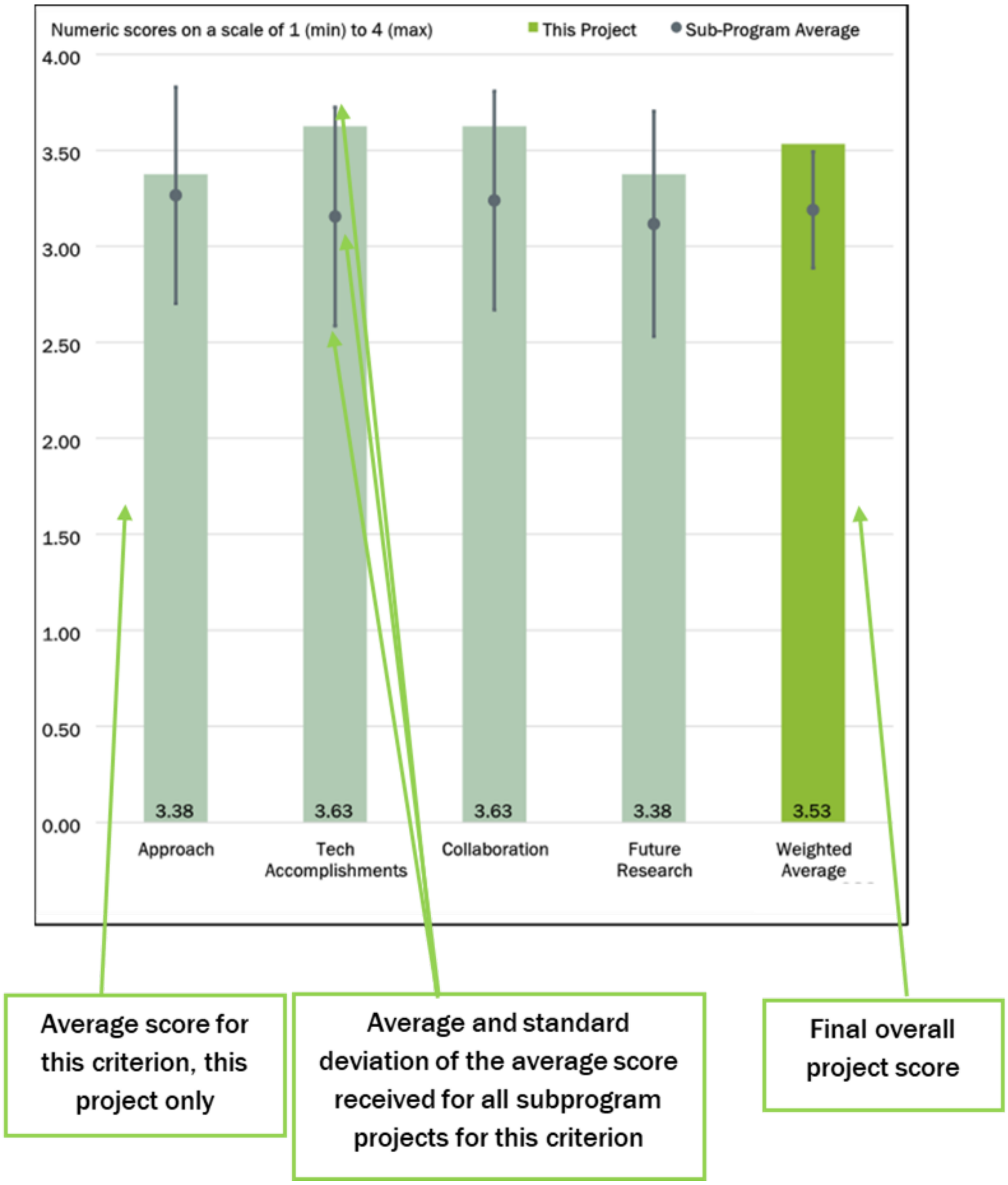

Figure 1. Sample Question 1 through Question 4 score averages, standard deviations, and overall Weighted Average for an R&D subprogram project

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 (as shown above) 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.

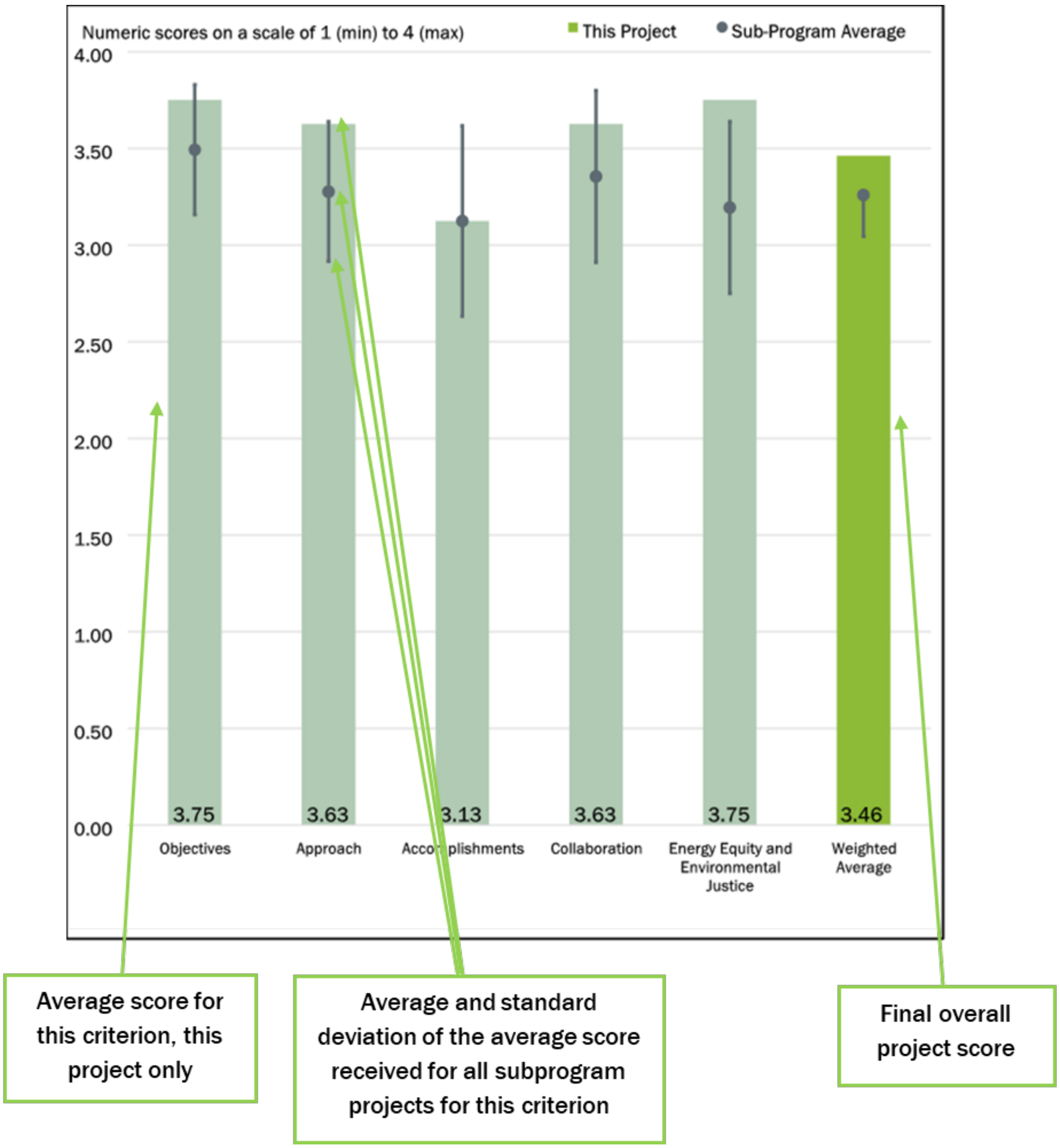

Figure 2. Sample Question 1 through Question 5 score averages, standard deviations, and overall Weighted Average for a TI subprogram project

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, a subprogram activities score summary table (and page numbers), project-specific reviewer evaluation comments with corresponding bar graphs, and a list of acronyms and abbreviations.

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1. Decarbonization of Off-Road, Rail, Marine, and Aviation Program

The Vehicle Technologies Office (VTO) supports research, development, deployment, and demonstration (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. The office's investments leverage the unique capabilities and world-class expertise of the national laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies and systems (including automated and connected vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement); combustion engines to reduce greenhouse gas (GHG) emissions; and technology deployment and integration at the local and state level. In coordination with the other offices across the Office of Energy Efficiency and Renewable Energy (EERE) and the U.S. Department of Energy (DOE), the Vehicle Technologies Office advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

The VTO Decarbonization of Off-Road, Rail, Marine, and Aviation (formerly Advanced Engine and Fuel Technologies) subprogram supports research and development (R&D) necessary for industry to develop efficient engines that can utilize renewable fuels, such as advanced biofuels, hydrogen, and e-fuels, to reduce GHG emissions and achieve a net-zero economy by 2050, all while creating good paying jobs with the free and fair chance to join a union and bargain collectively. Internal combustion engines will continue to be an important power source for off-road vehicles including construction, agriculture and forestry, and rail and marine, during the next several decades. Increasing their efficiency and reducing GHG and criteria emissions will ensure that the clean energy economy benefits all Americans. Optimization of high-efficiency engines and emission control systems, integration of hybrid and electrified powertrains, and utilization of renewable fuels has the potential to improve heavy-duty engine efficiency.

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.

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
ace023	Controlling NOx Reduction and Low Temperature Oxidation	Yong Wang (Pacific Northwest National Laboratory)	1-8	3.38	3.63	3.63	3.38	3.53
ace027	Fundamental Understanding of Copper-Zeolite Selective Catalytic Reduction (SCR) Catalyst Aging Mechanism (Cummins CRADA)	Feng Gao (Pacific Northwest National Laboratory)	1-12	3.50	3.63	3.75	3.00	3.53
ace100	Improving Transportation Efficiency through Integrated Vehicle, Engine, and Powertrain Research - SuperTruck 2	Darek Villeneuve (Daimler Trucks North America)	1-16	3.20	2.80	3.20	2.63	2.93
ace101	Volvo SuperTruck 2, Pathway to Cost-Effective Commercialized Freight Efficiency	Eric Bond (Volvo Trucks North America)	1-22	2.90	3.00	3.40	2.88	3.01
ace102	Cummins-Peterbilt SuperTruck 2	Jon Dickson (Cummins)	1-28	3.80	3.70	3.60	3.75	3.72
ace103	Development and Demonstration of a Fuel-Efficient Class 8 Tractor and Trailer SuperTruck	Russell Zukouski (Navistar)	1-33	3.80	3.50	3.30	3.50	3.55

ace124	SuperTruck 2 - PACCAR	Maarten Meijer (PACCAR)	1-38	3.67	3.42	3.25	3.08	3.42
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)	1-44	3.10	3.40	3.20	2.80	3.23
ace151	Hierarchically Informed Engineering Models for Predictive Modeling of Turbulent Premixed Flame Propagation in Pre-Chamber Turbulent Jet Ignition	Haifeng Wang (Purdue University)	1-49	3.20	3.20	3.10	3.00	3.16
ace152	Development of High-Fidelity and Efficient Modeling Capabilities for Enabling Co-Optimization of Fuels and Multi-Mode Engines	Matthias Ihme (Stanford University)	1-55	3.20	3.10	3.10	3.00	3.11
ace154	Heavy-Duty Hybrid Diesel Engine with Front-End Accessory Drive-Integrated Energy Storage	Chad Koci (Caterpillar)	1-60	3.00	3.00	2.80	3.38	3.02
ace155	Low-Mass and High-Efficiency Engine for Medium-Duty Truck Applications	Qigui Wang (General Motors Company)	1-64	3.50	3.25	3.38	3.38	3.34

ace156	Next-Generation, High-Efficiency Boosted Engine Development	Michael Shelby (Ford Motor Company)	1-68	3.50	3.17	3.17	3.17	3.25
ace158	Slashing Platinum Group Metal (PGM) in Catalytic Converters: An Atoms-to-Autos Approach	Wei Li (General Motors Company)	1-71	3.50	3.00	3.50	3.17	3.21
ace159	Reduced Cost and Complexity for Off Highway Aftertreatment	Ken Rappe (Pacific Northwest National Laboratory)	1-74	3.50	3.20	3.40	3.20	3.30
ace160	Optimization and Evaluation of Energy Savings for Connected and Autonomous Off-Road Vehicles	Zongxuan Sun (University of Minnesota)	1-79	3.07	3.00	3.29	2.79	3.03
ace161	New Approach for Increasing Efficiency of Agricultural Tractors and Implements	Andrea Vacca (Purdue University)	1-86	3.58	3.50	3.42	3.33	3.49
ace162	Improved Efficiency of Off-Road Material Handling Equipment through Electrification	Jeremy Worm (Michigan Technological University)	1-92	2.67	2.58	2.42	2.58	2.58
ace163	Ducted Fuel Injection and Cooled Spray Technologies for Particulate Control in Heavy-Duty Diesel Engines	Adam Klingbeil (Wabtec)	1-97	3.00	3.00	3.20	3.00	3.03
ace166	New Two-Cylinder Prototype Demonstration and Concept Design of a Next Generation Class 3-6 Opposed Piston Engine	Fabien Redon (Achates Power)	1-97	3.00	2.83	3.17	3.08	2.95

ace169	Greatly Reduced Vehicle Platinum Group Metal (PGM) Content Using Engineered, Highly Dispersed Precious Metal Catalysts	Yong Wang (Washington State University)	1-108	3.25	3.25	3.63	3.25	3.30
ace170	LLCF Effects on Emissions Control Catalyst Performance and Durability	Sreshtha Sinha Majumdar (Oak Ridge National Laboratory)	1-112	3.75	3.75	3.38	3.63	3.69
ace171	Simultaneous Greenhouse Gas and Criteria Pollutants Emissions Reduction for Off-Road Powertrains	James McCarthy (Eaton)	1-116	3.38	3.25	3.50	3.25	3.31
ace172	Fast Simulation of Real Driving Emissions from Heavy-duty Diesel Vehicle Integrated with Advanced Aftertreatment System	Hailin Li (West Virginia University)	1-120	2.50	2.38	2.88	2.38	2.47
ace173	Comprehensive Integrated Simulation Methodology for Enabling Near-Zero Emission Heavy-Duty Vehicles	Andrea Strzelec (University of Wisconsin-Madison)	1-124	3.13	3.13	3.25	3.25	3.16
ace175	Co-optimization of fuel physical/chemical properties and combustion system for mixing controlled compression ignition (MCCI) in a medium-duty engine	Flavio Chuahy (Oak Ridge National Laboratory)	1-128	3.50	3.40	3.60	3.70	3.49

ace177	Independent Fuel Property Effects of Fuel Volatility on Low Temperature Heat Release and Fuel Autoignition	Sibendu Som Jim Szybist (Argonne National Laboratory and Oak Ridge National Laboratory)	1-133	3.30	3.20	3.50	3.40	3.29
ace178	Development Of Advanced Combustion Strategies for Direct Injection Heavy Duty Liquefied Petroleum Gas (LPG) Engines	Dan Olsen (Colorado State University)	1-139	3.38	3.50	3.50	3.25	3.44
ace179	Propane longstroke engine R&D	Derek Splitter (Oak Ridge National Laboratory)	1-143	3.67	3.33	3.33	3.50	3.44
ace182	Fully Electric Powered, Hydraulic Assisted, Compact Track Loader	Perry Li (University of Minnesota)	1-146	3.21	2.71	2.86	3.14	2.91
ace183	Articulated Dump Truck (ADT) Electrification - Greenhouse Gas Reductions and Commercialization of New Technology	Brij Singh (John Deere)	1-152	3.00	2.75	2.50	2.75	2.78
ace184	Development of a Flex-Fuel Mixing Controlled Combustion System for Gasoline/Ethanol Blends Enabled by Prechamber Ignition	Adam Dempsey (Marquette)	1-157	3.63	3.38	3.50	3.25	3.44
ace186	Dynamic Skip Fire (DSF) on a Heavy-Duty Natural Gas Engine	Jay Shah (Cummins)	1-161	3.30	3.30	3.20	3.40	3.30

ace187	Opposed-Piston Two-Stroke Hybrid Commercial Vehicle System	Fabien Redon (Achates Power)	1-166	2.67	2.67	2.92	2.58	2.69
Overall Average				**3.27**	**3.15**	**3.24**	**3.12**	**3.19**

Presentation Number: ace023
Presentation Title: Controlling NOx Reduction and Low Temperature Oxidation
Principal Investigator: Yong Wang, Pacific Northwest National Laboratory

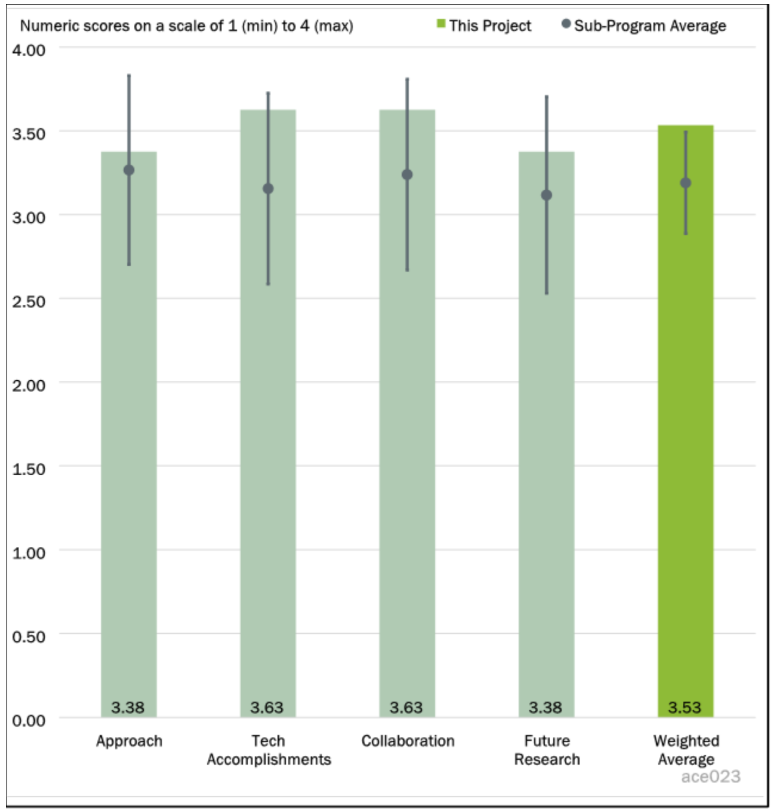

Figure 1-1 - Presentation Number: ace023 Presentation Title: Controlling NOx Reduction and Low Temperature Oxidation Principal Investigator: Yong Wang, Pacific Northwest National Laboratory

Presenter

Yong Wang, PNNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said the approach laid out by the team to address the critical barriers is impressive. The approach focused on applications and commercialization makes fundamental research such as this relate to better product development. The reviewer said the project approach bridges the gap between fundamental research and real-world applications and issues.

Reviewer 2

The reviewer remarked there are so many projects, at least five, covered by this review of a set of core issues that it is hard to evaluate them easily or well. But the sum of all the work is outstanding in advancing knowledge in important areas of catalysis. The approach to each topic is well matched to the information needed about that system.

Reviewer 3

The reviewer said the Pacific Northwest National Laboratory (PNNL) team is confronting several problems from fundamental approach; these include lab aging protocol development, low temperature selective catalytic reduction (SCR), nitrous oxide (N_2O) formation in SCR, single atom catalysts (SAC) for methane oxidation, and non-platinum group metal (PGM) oxidation catalyst. Each of these could be the single focus of a research team. To their credit, advances made are being published in top journals, indicating that the science meets high standards. On the other hand, the findings have at this point limited application. The reviewer said that efforts should be made to focus on 1-2 problems with input from industry stakeholders.

Reviewer 4

The reviewer said this project, over the years, has delivered a significant amount of knowledge to the field. With changes in funding, however, the project needs to re-focus and prioritize. It can no longer continue to support the large variety of efforts it has in the past. Thus, the project should be re-designed. The reviewer said that with too many projects ongoing, focus is lost and timelines likely unrealistic. It is acknowledged that these comments are a direct consequence of funding changes.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer said that significant progress has been made to understand the activity and aging of SCR, and interesting findings on N_2O formation.

Reviewer 2

Of the many projects studied the work on low-temperature carbon monoxide (CO)-oxidation on copper (Cu)-ceria (CeO_2) and the study of platinum on CeO_2 supporting palladium oxide rafts for water-tolerant methane oxidation are quite important for saving PGM and expanding the range of conditions where methane oxidation is possible. The reviewer said that much has been learned about inhibiting N_2O formation during SCR reactions and should be continued.

Reviewer 3

The reviewer remarked that considering the multiple sub-projects, the team did well in making progress towards better understanding the science and developing new catalyst technologies. A better definition of specific barriers (or even singular given the many projects) that each sub-project is directed towards will help.

Reviewer 4

The reviewer said the technical accomplishments at the fundamental level are strong based on the dissemination of findings in reputable journals. It is less clear that the findings are translating into commercial practice.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer remarked the number and quality of the collaborators for this project was excellent, even considering the number of topics it covers.

Reviewer 2

The reviewer said it is apparent that there is good collaboration amongst several of the partners. It is not as clear how strong the collaborations are with the industry partners, but it is for the academic and national lab partners.

Reviewer 3

The reviewer said the project has a large industry collaboration, which makes this work highly application-oriented and geared towards original equipment manufacturer (OEM) and Tier 1 suppliers to develop better emissions control system.

Reviewer 4

The reviewer remarked the PNNL team should strive to improve the input of practitioners. For example, comparisons should be made of findings to commercial catalysts and operating conditions. This would better frame the results and help practitioners implement upgrades.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said that continuing many of the same projects, especially those on greenhouse gas (GHG) (e.g., N_2O) from the SCR reaction in off-road engine vehicles, will lead to important further understanding. Emissions work on exhaust from engines with low carbon fuels is important, although we did not see much presented in the past year's summary.

Reviewer 2

The reviewer said the list included low load cycles, full useful life, fuels, GHG, and PGM use as remaining challenges and barriers—this is a massive list. The future research list is also long and unfortunately not focused. The reviewer noted that it contains ammonia (NH_3) SCR, and that seems to be a focus, but also contains PGM usage. A focused project seems more appropriate and would yield deeper knowledge.

Reviewer 3

The reviewer asked what is the limit of low-temperature SCR activity? Will urea hydrolysis be a bigger issue for lower temperature SCR activity? Should propane and dimethyl ether (DME) also be considered as possible fuels to assess low-temperature emissions control? Finally, the reviewer asked should the low-C fuel challenges include a potential of SCR for hydrogen (H_2) internal combustion engines (ICE)?

Reviewer 4

The reviewer said the research plan is more of the same with no plan to consolidate. This approach needs to be re-thought.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer commented the relevance of this group of projects is high, especially those on GHG studies and low temperature emissions from off-road vehicles.

Reviewer 2

The reviewer said this project addresses the VTO program objectives of developing cleaner and efficient diesel engines.

Reviewer 3

The reviewer said the project is focused on engine emissions.

Reviewer 4

The reviewer said the problems studies are relevant at fundamental level, though the translation to real world aspects were less clear.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer remarked the funds are certainly adequate to support the fundamental research of several problems, and the team should consider consolidating the focus to make a larger impact on 1-2 problems.

Reviewer 2

The reviewer said the project team is equipped with a lot of OEM expertise, state-of-the-art equipment, and fundamental knowledge of catalyst chemistry to address the critical barriers of this study.

Reviewer 3

The reviewer said resources for these studies exist at PNNL in abundance and at their collaborators' laboratories, if needed.

Reviewer 4

The reviewer said that given the significant drop in funding from fiscal year (FY) 2021 to FY 2022, the focus of the project needs to be re-evaluated. The list of future work surpasses the resources for FY 2022.

Presentation Number: ace027
Presentation Title: Fundamental Understanding of Copper-Zeolite Selective Catalytic Reduction (SCR) Catalyst Aging Mechanism (Cummins CRADA)
Principal Investigator: Feng Gao, Pacific Northwest National Laboratory

Presenter

Feng Gao, PNNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

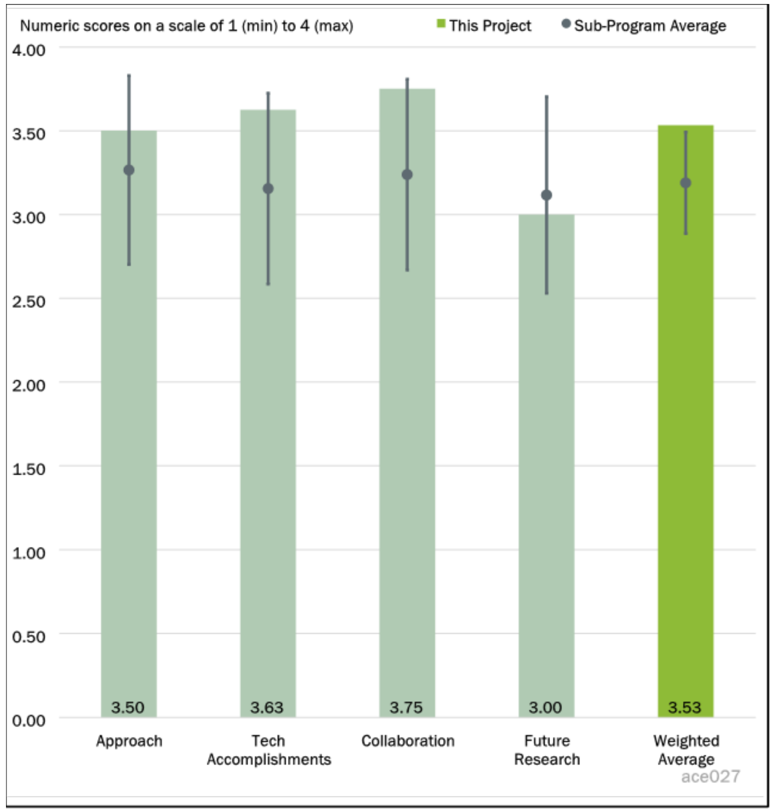

Figure 1-2 - Presentation Number: ace027 Presentation Title: Fundamental Understanding of Copper-Zeolite Selective Catalytic Reduction (SCR) Catalyst Aging Mechanism (Cummins CRADA) Principal Investigator: Feng Gao, Pacific Northwest National Laboratory

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said the approach to studying aging of SCR catalysts in comparison with real world catalysts was excellent. Sulfur poisoning is also addressed, a well-known barrier in many studies.

Reviewer 2

The reviewer said the project approach is well designed to address the gaps in field-aging versus simulated again of catalyst. The approach clearly focuses on the studying the mechanism of sulfur poisoning and HTA on the catalyst aging. Will the study consider the effect of incomplete urea decomposition deposits on catalyst aging?

Reviewer 3

The reviewer said the PNNL team has made good progress in characterizing, via electron paramagnetic resonance spectroscopy (EPR) and kinetic studies, changes in SCR catalysts with exposure to real-world aging (RWA) and sulfur. Their strength is in catalyst characterization and the team has developed EPR to study SCR catalysts. The reviewer noted the team has also used TPR to identify catalyst traits. The EPR has proven a useful tool, and although there are some still ambiguous details regarding data obtained using it in combination with the kinetics, gains are being made. The reviewer noted there is a question regarding how this characterization will ultimately be used to design a better system or slow degradation that would be meaningful in considering the impact.

Reviewer 4

The reviewer said catalyst characterization efforts have been comprehensive and milestones on that aspect have been fine. The collaboration between PNNL and Cummins is strong. The reviewer said what is less evident is how characterization will be translated to fundamental understanding of the mechanism and associated kinetics.

The two objectives—Characterize field-aged samples, identify and model the changes in active sites; and Develop accelerated procedures to simulate RWA of SCR catalysts—need to be emphasized to have a successful outcome to the project. The reviewer said it is unclear what "model" implies. Is this an empirical, statistical, or fundamental model?

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer commented that results showing the effect of HTA and HTA+sulfur oxide (SO_x) aging on the efficiency of the SCR is excellent. This is important to develop diagnostics of SCR catalysts. The project team has addressed previous reviewer comments effectively.

Reviewer 2

The reviewer said learning that lab aging tended to show more harsh hydrothermal aging than real world catalysts, while real world aging tended to have more impact from sulfur than seen from lab aging, is a very important finding for planning and modeling aging in these SCR catalysts.

Reviewer 3

The reviewer said the characterization and kinetics are solid contributions to the project. The decoupling of hydrothermal aging and sulfur, and the focus on the latter as the more important problem, helps the field. The reviewer remarked the inability to "see" particles although they are proposed to form is problematic. This should be a focus to confirm the assumptions behind the other techniques.

Reviewer 4

The reviewer remarked results on identifying the different contributions to the aging using TPR diagnostic is clever and translatable to other labs. However, the project has not yet demonstrated how this will be connected at the fundamental level in terms of mechanism and quantification.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said it is apparent that there are strong interactions with the industry partner.

Reviewer 2

The reviewer noted that Cummins is an excellent partner for this cooperative research & development agreement (CRADA) work with them, along with interactions with Jeff Miller at Purdue and the studies of operando measurements at Tsinghua University in Beijing.

Reviewer 3

The reviewer said testing of field-aged samples is vital to this study and collaboration with Cummins is the best approach to prepare these samples accurately. The collaboration between the Environmental Molecular Sciences Laboratory and Purdue also provides the requires instrumentation for this work.

Reviewer 4

The reviewer remarked collaboration so far has been excellent. Less clear is how data generated at PNNL will be translated to the "real world" with Cummins involvement.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said future model development incorporating sulfur poisoning, sulfur aging mechanism, and NH_3 storage is vital to understanding the effect of aging on the SCR functionality as a whole. These are excellent future research directions. The reviewer said N_2O formation needs more understanding and it is great to see it in the list of future research. The addition of urea deposit formation and its effect on SCR functionality would also be of interest.

Reviewer 2

The reviewer remarked it appears that the future work is primarily on the industry partner. There is a note that the team will shift to "off-road", but it is not clear what research will be performed.

Reviewer 3

The reviewer said future work described is very appropriate. More direct evidence of the interesting formation of oxidized Cu aggregates in the aged catalyst would very good to see as suggested in Slide 12 of the talk.

Reviewer 4

The reviewer commented future work needs to converge on how fundamentals will translate to an accelerated aging protocol.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said the project supports the VTO goal of developing cleaner and more efficient ICE for transportation and off-road applications.

Reviewer 2

The reviewer said nitrogen monoxide (NO) emissions control from diesel engines is important.

Reviewer 3

The reviewer remarked this work is very relevant to the increased off-road focus of the CRADA, because it relates to the same engines used in those systems.

Reviewer 4

The reviewer pointed out that the aging of SCR and resulting effect on catalyst performance is paramount. This project aims to connect fundamental measurements to understanding the underlying aging, and to translate that to devising accelerated aging that captures the real-world aging.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer remarked resources contributed 50:50 between federal and industrial partners are fine.

Reviewer 2

The reviewer noted the project's team members bring in an abundance of experience, stat-of-the-art equipment, and modeling capabilities.

Reviewer 3

The reviewer said this one is difficult to gauge—the future work is on the industry partner, so maybe funds are not required by PNNL. But the transition to off-road is mentioned although no details were provided.

Reviewer 4

The reviewer said both PNNL and Cummins have quite sufficient resources to devote to this project.

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

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

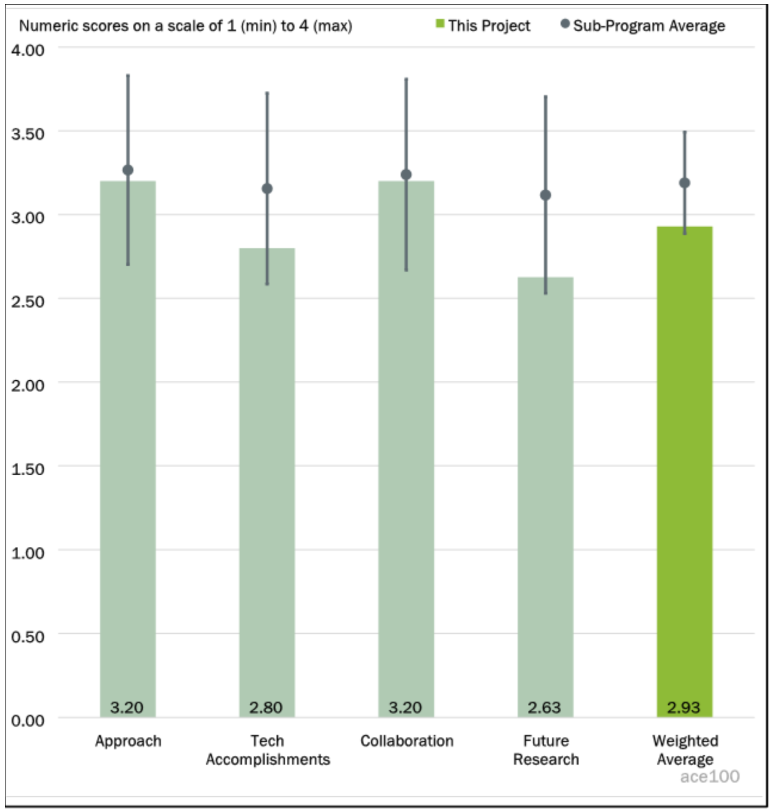

Figure 1-3 - Presentation Number: ace100 Presentation Title: Improving Transportation Efficiency through Integrated Vehicle, Engine, and Powertrain Research - SuperTruck 2 Principal Investigator: Darek Villeneuve, Daimler Trucks North America

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said overall, this team has taken a comprehensive approach to meeting the efficiency goals. In most cases, these have been successful.

Reviewer 2

The reviewer noted the project is in Phase 5, approaching final demonstration vehicle testing scheduled in third quarter with project completion expected by end of third quarter 2022. The project evaluated and effectively selected multiple technologies for the demonstration vehicle to achieve the goals of exceeding 115% freight efficiency, and the engine brake thermal efficiency of 55%. The reviewer said significant challenges identified by the project are optimizing hybrid operations, and software refinement. Predicted aerodynamic performance from analysis and test overestimated gains are seen on road, but the project had sufficient margin. The project, with extension due to COVID ramifications, is on track to complete and is successfully meeting or exceeding these two goals. The reviewer remarked in light of the challenges due to COVID and worldwide supply chain issues, the project has been executed well. Commercialization of the technologies with respect to a 3-year return on investment (ROI) were not discussed in any detail, although the project did have meetings with fleets to get early feedback on design choices.

Reviewer 3

The reviewer said the approaches taken on the vehicle side seems to be a little bit conservative because the stretching goal is only 125% better than the 2009 baseline, while SuperTruck I already showed 115% improvement. It seems that the program is more toward production-intent technologies rather than taking a more aggressive R&D approach, which is what DOE would like to see. The reviewer noted these observations may be partially due to the material and information presented, which contains fairly little detail on the technical approaches. For example, there is little or no information on weight reduction, and it is not clear how the advanced tires compare to baseline.

The reviewer remarked that on the engine side, it seems that the team has all they need to achieve the program, but due to the budget limitation as well as their early poor planning, one of the most advanced technologies, phase change cooling waste heat recovery (WHR), would not be able to be implemented into the dynamometer cell. Lack of this key technology makes this project unable to achieve the program's 55% brake thermal efficiency (BTE) goal.

Reviewer 4

The reviewer has been very impressed with the approach from this program team throughout SuperTruck II. But, this review was very unimpressive. Seemed to be many slides and details presented here from the last review. The reviewer said there was not much to be done in this last phase, but the reviewer would have liked to see more details on commercialization including the required efforts on total cost of ownership of concepts.

Reviewer 5

The reviewer remarked it seems like the timeline is going well, but the reviewer would have expected the 55% BTE engine to have already been demonstrated. It also would have been good to have more discussion on commercialization plans and costs for the technologies that are being developed under this program.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer thought the team has done a good job to meet the objectives of the project. Compared to some of the other teams, this reviewer did not see this team going above and beyond in as many areas and really pushing limits. The reviewer would have liked to see a bit more innovation—for example, the new tire design by Michelin and the ability to convert to 6x2 at highway speeds is extremely interesting. But on the other hand, the cab design was not a bottom-up design it was just a modification of the SuperTruck I design.

The reviewer understood that the 55% BTE engine would not be utilized on the demonstration vehicle as it was not a requirement of the SuperTruck 2 project, but this reviewer was disappointed that most of the SuperTruck teams would choose not to put the 55% BTE engines in their vehicle demonstration.

Reviewer 2

The reviewer said the project evaluated and effectively selected multiple technologies for the demonstration vehicle to achieve the goal of exceeding 115% freight efficiency, and the engine BTE of 55%. However, the two targets were not tied together, so the final demonstrator vehicle does not have the same technology as the 55% BTE engine because WHR is not on the demonstrator vehicle. The SuperTruck II teams interpreted the project expectations, and the DOE apparently did not specifically require the 55% BTE engine to be in the 115% freight-ton efficiency (FTE) vehicle. The 115% target and 125% stretch target are less aggressive than some of the other SuperTruck II teams' targets. The reviewer said the commercial viability return on investment of the technologies was not reported in this AMR review, however the team did report scaling back on some aerodynamic choices based on fleet engagement due to concerns over commercial viability. The reviewer noted that analysis was reported as supporting exceeding the 115% FTE, so final physical testing is expected to be low risk in confirming this achievement with some margin of safety. The decision to have different tires on each of the tandem axles is technically sound, but introduces additional operational risks to fleets where these tires are moved to trailers or retreaded.

Reviewer 3

The reviewer said most of the technical accomplishments were very good. It is extremely unfortunate that the phase change cooling will not be demonstrated, and that only simulation from the supplier (who is not a collaborator) is being used to claim meeting the 55% BTE goal. As a reviewer, this person has to see this as a failure to meet the target.

The reviewer said the freight efficiency goal is still expected to be met with the final demonstration yet to occur, although underperforming the simulation predictions.

Reviewer 4

The reviewer was disappointed that some of the developed systems such as WHR did not make it into the final vehicle, and it seems like the final prototype could have been more aggressive.

Reviewer 5

The reviewer's biggest concerns on this program is the technical accomplishments on the engine side. The roadmap to 55% BTE seems to point to the disappointing direction that the program would not be able to achieve 55% BTE experimentally. The reviewer said it is even more disappointing that the phase change cooling WHR would not even be scheduled for the next tests (Slide 15). Also, it is not clear whether there is any WHR being used in the program, because the program has been dedicated too much on phase change cooling WHR and it would be hard to imagine that it would have resource for two WHR programs—one with a "conventional WHR" and other with phase change cooling WHR, even though the roadmap to 55% BTE on Slide 9 shows 2.3% benefits from WHR. The reviewer said if this came from the previous testing assuming an additive to the total BTE, this program would only achieve 50.6% BTE, which would be a total failure of the program. The reviewer asked the team to please clarify on this important matter.

The reviewer said technical accomplishments on the vehicle side seem to be fair, but the team only achieved no more than a 125% improvement compared to the 2009 baseline, and it is only 10% point better that SuperTruck I. The reviewer said there are very few details to demonstrate the progress on the vehicle side. It is not even convincing or even confusing how the progresses related to energy storage, low temperature cooling system, and stationary eAC testing mentioned on Slide 7 help to achieve 125% improvement goals, partially due to the way how the material is presented. The reviewer said that in addition, it is disappointing that no WHR technology is being installed in the vehicle, making this program much less competitive compared to its competitors in view of the progress on the engine side.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said the project effectively engaged with fleet, suppliers, and research groups to accomplish its objectives. Schneider National, Strick Trailers, Michelin, Oak Ridge National Laboratory (ORNL), National Renewable Energy Laboratory (NREL), University of Michigan, Clemson University, and Solution Spray

Technologies were specifically called out in the review as participants, and others were also involved as suppliers.

Reviewer 2

The reviewer remarked it looks like a very good team has been assembled for this project. The reviewer thought it is great that Schneider was one of the partners. If there is an opportunity it would be great to hear directly from them on how they perceive the results of the in-use demo.

Reviewer 3

The reviewer said perhaps IAV should have been a partner so that they would have had more skin in the game, so to speak. The listed partners on Slide 17 all made significant contributions.

Reviewer 4

The reviewer remarked the team has all the partners needed, but it is clear that some of partners are unable to help the program to achieve the engine 55% BTE experimentally.

Reviewer 5

The reviewer said that coordination across suppliers and technology companies seems strong, but the reviewer again voiced concern about the lack of customer and voice of customer input and actions. The team claims this was done, but shared virtually no evidence. The reviewer said this was particularly alarming as this was a requirement, investigation of commercialization with total cost of ownership for this program. The reviewer was disappointed we did not see this across any of the programs.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer remarked the project is in its final Phase 5 due to complete in quarter three 2022, so it is essentially ended. Future work is not funded under SuperTruck II as SuperTruck 3 is an entirely new, non-diesel program. The reviewer remarked aerodynamic improvement through tractor ground aerodynamics and trailer aerodynamics, hybrid optimization, and routing strategy were proposed as future areas for vehicle research. The reviewer noted that future engine research proposed includes extending durability of cylinder coatings and new combustion approaches. This team specifically called out that final engine testing with phase change cooling WHR remains unfunded but planned to be completed.

Reviewer 2

The reviewer found it hard to judge this area—not a lot of details are given on the future research plan. That being said, the reviewer thought the overall targets are laid out clearly and the reviewer did not have any concerns about the trajectory of the future research.

Reviewer 3

The reviewer said we should see detailed test reporting and total cost of ownership analysis results as part of this program closeout, although no commitments were made in this review. A press release/ event should be completed after results and analyses are finalized.

Reviewer 4

The reviewer found it surprising that the phase change cooling WHR would not even be mentioned in the proposed future research. It seems that the program completely abandons this promising technology due to poor budgeting and planning in the early stage of the program.

Reviewer 5

The reviewer said the project is ending in 2022, so little DOE sponsored work is expected. Perhaps Daimler will have a chance in the future to wrap up a couple loose ends that seem to exist on this project.

Question 5: Relevance: Does the project support the overall VTO subprogram objectives?

Reviewer 1

The reviewer said improved efficiency supports the objective of the Advanced Engine and Fuel Technologies program.

Reviewer 2

The reviewer said highly relevant given $6/gallon diesel fuel and the demands of GHGp2 and likely 3 requirements. This program is more relevant than even Daimler and the DOE are sharing. So much, maybe there is too much focus in communications on zero-emission vehicles. The reviewer said let's be proud of what has been accomplished and share it. More than just in the new program launches that the reviewer expects are coming soon.

Reviewer 3

The reviewer said this program does support the overall VTO objectives.

Reviewer 4

The reviewer noted that the SuperTruck II program in 2016 was very relevant to DOE goals, but diesel technology improvement seems to have been eclipsed in priority by zero and near-zero emission technology and market growth for commercial vehicles. However, diesels, from market demand and production rates, will still be coming out in significant numbers for the next decade and will be in use longer due to their long lives. The reviewer said the SuperTruck II program is however showing continued improvement for diesels and may see some of the technologies in production in parallel with new zero emission and near-zero emission vehicles.

The reviewer noted that DOE has now greater investment in a broader, multi-path approach to improving commercial vehicle efficiency beyond SuperTruck II diesel research. The SuperTruck II project timing is in parallel to industry development of battery electric vehicles, hydrogen fuel cell electric vehicles, autonomous vehicles, and a variety of hybrid technologies along with continued work on ICE engine refinement with multiple fuels such as renewable diesel, renewable natural gas (RNG), H_2, and other fuels to address both efficiency and reduce emissions. Infrastructure technology for these alternatives is also now a priority for DOE investment.

The reviewer noted that WHR is appearing to be not commercially viable based on conclusions from at least three of the five SuperTruck II teams. WHR may not be commercially viable in the remaining timeline of fossil fuel diesels versus zero emission and near-zero emission market adoption. The reviewer said aspects of the 55% BTE engine development with respect to friction reduction and coatings may be applicable to a range of engines in the near term. Aerodynamics, light weighting, and mild hybridization investigated in this project appear to be relevant to future commercial vehicles and DOE objectives. Development of new cabs and chassis have some potential to impact future designs, but they are still tied to diesel engine placement, so are less optimized to facilitate other powertrain choices.

The reviewer said the SuperTruck II project comparison to a 2009 baseline has some usefulness for continuity with prior SuperTruck I programs, but is less relevant to commercialization potential of the technologies in 2022 and beyond with respect to the 3-year ROI SuperTruck II goal, as the current truck buyers are not buying 2009 trucks, but much more capable 2022 trucks that have been through significant GHG 1, GHG 2, and commercial refinements in the period since 2009. These buyers also are now able to procure zero emission battery electric vehicles and other non-diesel alternatives.

Reviewer 5

The reviewer believed this project is very relevant, and thought it is important to especially focus on many technologies that will be important as the trucking sector transitions to zero-emission vehicles.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said that from the information provided, the resources seem sufficient.

Reviewer 2

The reviewer said financial resources seemed to be sufficient, but perhaps there were some other resources that fell short (COVID related?) that prevented the 55% BTE demo from being completed.

Reviewer 3

The reviewer said the project, with a time extension due to COVID ramifications, is on track to complete and successfully meet or exceed the primary two goals while somewhat overrunning DDC and Daimler Truck North America budgets, but not exceeding DOE funding. The reviewer noted that in light of the challenges due to COVID and worldwide supply chain issues, and other unexpected issues outside of the project's control, the project has been executed well. DOE AMR reviews could benefit from standardizing AMR reporting requirements on budget, requiring spend to date, funds remaining, and additional detail to help reviewers determine resource adequacy. This could be done through a first page template.

Reviewer 4

The reviewer said resources are sufficient to complete, but expect to include a public sharing.

Reviewer 5

The reviewer said that if 55% BTE needs to be experimentally demonstrated, the program would not have enough funding to complete the program.

Presentation Number: ace101
Presentation Title: Volvo SuperTruck 2, Pathway to Cost-Effective Commercialized Freight Efficiency
Principal Investigator: Eric Bond, Volvo Trucks North America

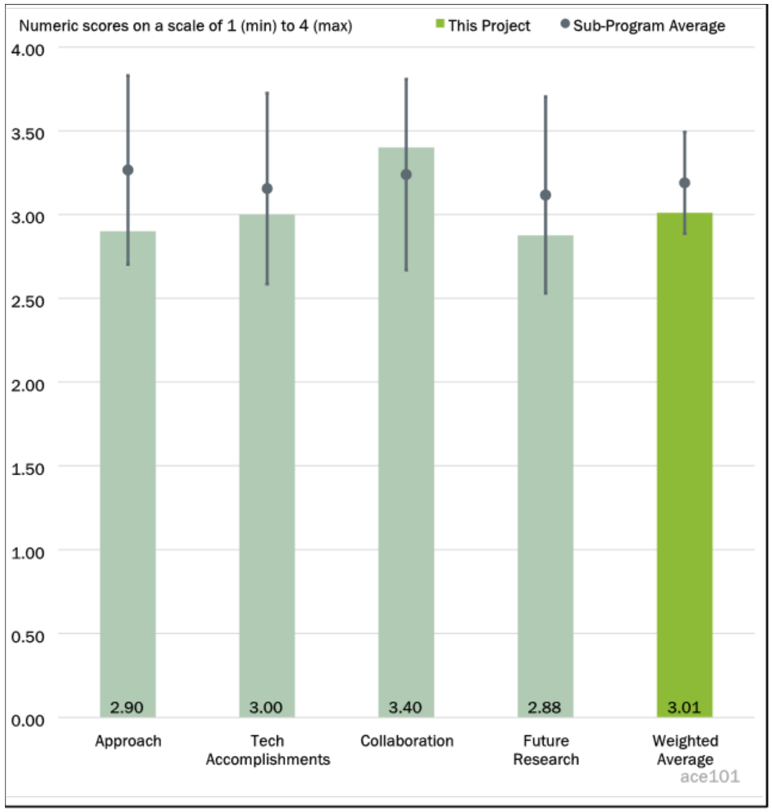

Figure 1-4 - Presentation Number: ace101 Presentation Title: Volvo SuperTruck 2, Pathway to Cost-Effective Commercialized Freight Efficiency Principal Investigator: Eric Bond, Volvo Trucks North America

Presenter

Eric Bond, Volvo Trucks North America

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said the team has good approaches to each specific goal for 55% BTE and 120% freight efficiency improvement. The concern here is that these seem to be two very separate pathways and not very integrated. The fuels work being done by University of Michigan also does not seem to be making a contribution towards either of the goals.

Reviewer 2

The reviewer said the team finished the project with gusto, and the reviewer is looking forward to seeing results presented after testing and total cost of ownership analysis is completed.

Reviewer 3

The reviewer really liked how the team did a lot of work to understand the most relevant duty cycle and combined vehicle weight and use that as the basis for their project plan. The reviewer would have thought the 55% BTE engine would have already been demonstrated at this stage, and would have appreciated more insights into commercialization plans and technology cost.

Reviewer 4

The reviewer noted the project is in its final phase expecting to be completed by December 2022. The team is on track to demonstrate greater than 100% FTE for the vehicle and 55% BTE for the engine. The team interpreted the DOE project goals in a way that the baseline 6x4 tractor capable of 80k lb. Gross vehicle weight was replaceable at 65k lb. as a 4x2. The reviewer remarked the engine used for 55% BTE testing is the larger 13L than the 11L engine installed in the vehicle demonstrator. The WHR system will not be part of the vehicle demonstrator. The reviewer said the 4x2 demonstrator vehicle is configured as a sleeper unit, which is somewhat contrary to the typical 4x2 market which are generally day cabs. The targeted demonstration vehicle improvements were less aggressive than some of the other SuperTruck II projects. The reviewer said overall, the project has accomplished or is on track to accomplish the individual project goals, but the path is somewhat disconnected.

Reviewer 5

The reviewer said there are a few fundamental flaws on the technical approaches taken in this program. First, different engine platforms are being used for the engine demonstration and vehicle demonstration. There are very little similarity or synergy between the 11L engine being used in the vehicle and the 13L engine being used in the engine demonstration, thus there is no integration between the engine and vehicle program, making these two programs separate, which provides little value to the overall program. The reviewer said many technologies being used in the engine dynamometer cell with 13 L engine has no opportunities to be applied to 11L engine used in the vehicle. The combustion system including different compression ratios is just one example, while the WHR developed from 13L engine would not be able to directly be applied to 11L engine.

Secondly, the reviewer remarked the 325 horsepower power rating for the 11L engine being used in the vehicle would be way too underpowered for the future Class 8 market.

Thirdly, the reviewer was not sure if there is any practical value to study the fuel property effect on the emissions, because there is no chance for the market to be able to accommodate the infrastructure of the new gas stations with the different fuel properties.

Fourthly, the reviewer said the 4x2 axle used in the program has very little chance that can be applied to market for Class 8 vehicles due to many practical reasons, such as lack of traction on slippery roads.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer remarked the projected has developed an advanced vehicle system including an all-new cab/sleeper with sleeper entry door and steps. The choice of 19.5-inch tires may impact operational tire life, while allowing a lower aerodynamic profile for improved fuel economy. The optimized powertrain with a 48V mild hybridization is a significant repackaging of the under-hood area. The reviewer noted that improvement from reducing friction and parasitic loads is a significant 1.9% on the 13L but it was not clear how much is achieved on the 11L demonstrator vehicle. The 55% BTE was accomplished for the 13L with WHR installed.

Reviewer 2

The reviewer remarked that team has shown excellent progress on individual pieces of the project, and demonstrations are in progress. I just wish there could be better connections between the two. I'm giving the benefit of the doubt in the rating, but am having a hard time seeing it, which may be getting lost in the 13L versus 11L engines and different CRs.

It would have been nice to see the freight efficiency improvement summarized in a stacked bar chart (like Slide 9 did for the engine efficiency demo).

Reviewer 3

The reviewer commented there were number of accomplishments that were very notable, innovative, and practical, including new, aerodynamic cab design with many nice interior features, all electric heating, ventilation, and air conditioning (HVAC), and more. My understanding was that the 55% BTE engine will not be utilized on the demonstration vehicle. I understand that this was not a requirement of the project, but it is disappointing that it seems like none of the SuperTruck II teams will be utilizing their 55% BTE engines in their vehicle demo.

Reviewer 4

The reviewer said that little evidence was presented to confirm total cost of ownership and the work done with customers. Presenters suggested that the work had been completed, but robustness and even results were not shared to the degree I expected to see. This program maintained and reported on the waterfall charts every year and were more open to share details.

Reviewer 5

The reviewer remarked there is little progress that has been made on the engine side in terms of hardware demonstration. As shown in Slide 9 - Progress - Validation of powertrain Technologies, the roadmap to 55% BTE still largely relies on simulations. It seems that at this time only less than 50% BTE has been demonstrated in an actual engine hardware.

The reviewer said there were not a lot of vehicle progress reported in this report, which only includes two slides (Slides 5 and 6). Similar to the engine programs, there are not a lot of tangible activities and progress that can be evaluated for the program progress.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer commented the project effectively engaged with fleets, suppliers, and research groups to accomplish its objectives. The partnership with Metalsa, Michelin, Wabash, Bergstrom, ORNL, University of Michigan, Motivo Engineering, Johnson Matthey, Mobil, Knight Transportation, and Wegmans has accomplished the primary project objectives.

Reviewer 2

The reviewer said good description of the team and areas of contribution on Slide 14. On Slide 7, ExxonMobil is mentioned (for some unknown reason), but they are not part of the team so their role is a bit undefined.

Reviewer 3

The reviewer found it hard to say too much about this question given that none of the partners are too involved in the presentation. It certainly seems as if a good, well-rounded team has been assembled. As mentioned above it does seem like there is close coordination with the partner fleets—the reviewer would be very interested to learn more about their perspective on the final demo vehicle.

Reviewer 4

The reviewer said good collaboration was evident across suppliers and technical organizations, but more customer focus group efforts would lead to better results and interesting commercialization input.

Reviewer 5

The reviewer remarked it seems that all partners play their role in assisting the program, but not sure if they are able to help Volvo to achieve the program goals.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

Plans to finish the project with testing and total cost of ownership conclusions were shared and seemed robust. I would like to see a press release and or event for Volvo to share the results with the public. This will ensure the appropriate sharing as we meet commitments for diesel efficiency going forward

Reviewer 2

The reviewer said that the team is completing the demonstrations on both the engine efficiency and freight efficiency. Project will be over soon, with no indication of whether any aspects of the project will carry forward towards future production product.

Reviewer 3

The reviewer commented that the project is entering is final phase and is due to complete by end of fourth quarter 2022, so it essentially ended with respect to AMR. Future work is not funded under SuperTruck II as SuperTruck 3 is an entirely new, non-diesel program. The reviewer noted the team hinted at future work with blended fuels but was unable to discuss details due to non-disclosure rules. No other new work was suggested by the team.

Reviewer 4

The reviewer said the future research listed is fine, but very scant details were given so the reviewer was not quite sure how to comment on this with any detail.

Reviewer 5

The reviewer remarked it seems that there would be a lot of challenges facing in the program, particularly on the engine program, and therefore one page that should be specifically dedicated to this Future work with a lot of details should be included. Rather, it only contains a few sentences on the future research.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer remarked advanced Engines and Fuels Technologies goals for improved efficiency were relevant in this project.

Reviewer 2

I believe this project is very relevant. I think the Volvo team has been strategic to focus on many technologies that will be important as the trucking sector transitions to zero-emission vehicles (ZEVs) and to also focus on ways to make those technologies the most useful and appealing to fleets, which is extremely important for consumer uptake and commercialization.

Reviewer 3

The reviewer said the SuperTruck II program in 2016 was very relevant to DOE goals, but diesel technology improvement seems to have been eclipsed in priority by zero and near zero emission technology and market growth for commercial vehicles. However, diesels, from market demand and production rates will still be coming out in significant numbers for the next decade and will be in use longer due to their long lives. The

SuperTruck II program is however showing continued improvement for diesels and may see some of the technologies in production in parallel with new zero emission and near zero emission vehicles.

The DOE has now greater investment in a broader, multi-path approach to improving commercial vehicle efficiency beyond SuperTruck II diesel research. The SuperTruck II project timing is in parallel to industry development of battery electric vehicles, hydrogen fuel cell electric vehicles, autonomous vehicles, a variety of hybrid technologies along with continued work on ICE engine refinement with multiple fuels such as renewable diesel, RNG, H_2, and other fuels to address both efficiency and reduce emissions. Infrastructure technology for these alternatives is also now a priority for DOE investment.

WHR is appearing to be not commercially viable based on conclusions from at least three of the five SuperTruck II teams. WHR may not be commercially viable in the remaining timeline of fossil fuel diesels versus zero emission and near-zero emission market adoption. Aspects of the 55% BTE engine development with respect to friction reduction and coatings may be applicable to a range of engines in the near term. Aerodynamics, light weighting, and mild hybridization investigated in this project appear to be relevant to future commercial vehicles and DOE objectives. Development of new cabs and chassis have some potential to impact future designs, but they are still tied to diesel engine placement, so are less optimized to facilitate other powertrain choices.

The SuperTruck II project comparison to a 2009 Baseline has some usefulness for continuity with prior SuperTruck I programs, but is less relevant to commercialization potential of the technologies in 2022 and beyond with respect to the 3-year ROI SuperTruck II goal, as the current truck buyers are not buying 2009 trucks, but much more capable 2022 ones that have been through significant GHG 1, GHG 2 and commercial refinements in the period since 2009. These buyers also are now able to procure zero emission battery electric vehicles and other non-diesel alternatives.

Reviewer 4

The reviewer said the project is very relevant given high fuel prices and the requirements of GHGp2 and 3. Even more relevant than the companies and DOE seem to share. Much has been learned with this program and we should share its successes as we finish.

Reviewer 5

The reviewer said this program does support overall VTO objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said the project appears to be on budget. This is admirable to do in spite of the NCTE.

Reviewer 2

The reviewer said from the information provided the resources seem sufficient.

Reviewer 3

The reviewer said resources are sufficient

Reviewer 4

The reviewer remarked the project, with a time extension due to COVID ramifications, is on track to completion and successfully meeting or exceeding the primary two goals without requiring additional funding from DOE. The team did not report spend to date versus plan, but no issues were raised about funding by the team. The reviewer noted that DOE AMR reviews could benefit from standardizing AMR reporting requirements on budget, requiring spend to date, funds remaining, and additional detail to help reviewers determine resource adequacy. This could be done through a first page template.

Reviewer 5

The reviewer said after reviewing the program with very little information on the progresses made, it is not sure if Volvo can complete the program goals with the current funding.

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

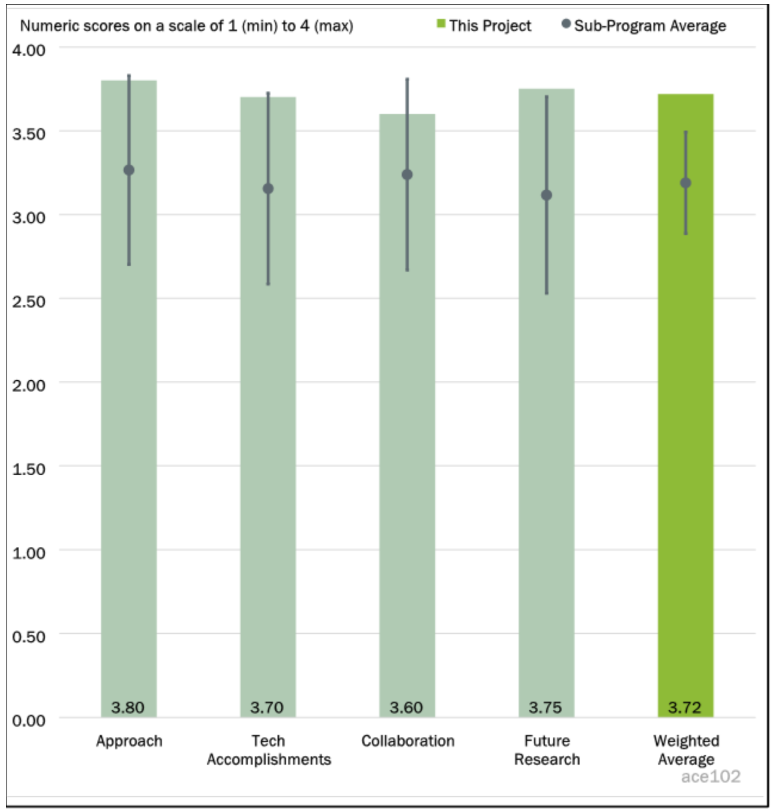

Figure 1-5 - Presentation Number: ace102 Presentation Title: Cummins-Peterbilt SuperTruck 2 Principal Investigator: Jon Dickson, Cummins-Peterbilt

Presenter

Jon Dickson, Cummins-Peterbilt

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said this past year, the Cummins/Peterbilt team has focused on the vehicle/trailer because the engine efficiency demo was completed last year and the team will be using the same engine system in the demo vehicle. The team has done an outstanding job on this SuperTruck II project.

Reviewer 2

The reviewer remarked the ACE 102 project is entering its final phase with vehicle testing expected in third quarter 2022 and project end in third quarter 2022. The approach is well organized with a 55% BTE engine demonstration that is implemented in the greater than 125% FTE demonstrator vehicle. The reviewer his project team set aggressive targets for improvement and greatly exceeded the goals while delivering a 6x4 vehicle with 55% BTE engine. Technical barriers have been dealt with effectively while maintaining continuity to the capabilities of the original 2009 baseline vehicle. In light of the challenges due to COVID and worldwide supply chain issues, the project has been executed well.

Reviewer 3

The reviewer thought the timeline and overall project were well designed, and would very much appreciate more input on commercialization status of the technologies as well as cost analysis.

Reviewer 4

The reviewer said the program is nearly complete, so plan delivered to date and work going forward for final freight efficiency test is underway.

Reviewer 5

The reviewer remarked all approaches taken seem to be all in the right direction, and it is clear that all program goals will be achieved.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer remarked the system approach to accomplishing goals for both the engine and the engine in the vehicle while meeting 55% BTE engine targets and projected to greatly exceed 125% vehicle targets demonstrates a range of technologies can be adequately packaged and operated without compromising the comparison to the original baseline 2009 vehicle. The weight reduction of 4,700 lb, aerodynamic drag reduction of 63%, and tire rolling resistance improvement of 33% contributes to an estimated 170% improvement versus the 6x4 2009 baseline while incorporating WHR and mild hybridization. The development of active aerodynamics, particularly on-board yaw sensors and the adjusting rubber extenders, reflect a significant advancement from passive aerodynamic systems. The lightweight hybrid steel/aluminum chassis is similarly innovative.

Reviewer 2

It is clear that a lot of great technical progress has been made. I think there are some areas where the team could have been a bit more innovative—such as a bottom-up cab design rather than modifications to the SuperTruck I design (at least this is what I understood from the presentation). The team was able to demonstrate their 55% BTE engine ahead of many of the other SuperTruck teams, which is very exciting. Unfortunately, my understanding is that none of the teams will be using their 55% engine in the vehicle demo (I understand it is not a requirement, but somewhat disappointing nonetheless). The solar panels on the trailer were interesting and I believe Cummins/Peterbilt was the only team that is looking at that technology. Also, a significant weight reduction was achieved, which is a very relevant and important development especially if it can be done cost effectively.

Reviewer 3

The reviewer said it is amazing to see that the technical progresses that have been made. There is no question that this would be one of the best programs DOE has funded. It should be mentioned that this is the only SuperTruck II program that includes WHR in the final vehicle demonstration, making this program way ahead of its competitors.

Reviewer 4

The reviewer said the team is on the path to achieving all efficiency goals.

Reviewer 5

Progress has been made, but I again am underwhelmed by the amount of data and information presented here. There is good detail in the reviewer slides, but the greater industry players should benefit more from these programs. Maybe a press release/event, where the team details the accomplishments and the technologies moving forward. I understand the competitiveness of solutions, but this program should be sharing more.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer remarked nice identification of where the collaborators contributed to the project.

Reviewer 2

The reviewer remarked the project effectively engaged with fleet, suppliers, and research groups to accomplish its objectives. Duty cycle characterization with NREL and Walmart was a significant addition to the knowledge base on real world operations. Partnerships with Magna, Point Innovation, Valeo, RC, Pilkington, Bergstrom, Northwest Rubber, IMI Noorgren, Great Dane, Mahle, RMC, ZF, and other suppliers show significant involvement of a wide range of expertise.

Reviewer 3

Obviously good coordination between Cummins and Peterbilt. Regarding the rest of the team, that is hard to judge based solely on the presentation. My main comment/question is that I understand Walmart is part of the team, but would appreciate more information on how the team is collaborating with them and how the team is iterating your designs and work based on their feedback.

Reviewer 4

The reviewer would have liked to see more on the customer engagement. The team talks about getting customer buy-in on concepts, but little to no evidence has ever been showed during these annual reviews.

Reviewer 5

The reviewer said collaboration and coordination seem to be seamless with all partners.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said thank you for giving some specifics on future research. This is helpful to understand what remaining work the team has remaining.

Reviewer 2

The reviewer said the project is finishing in September 2022, so future work is not expected to go beyond the ending date.

Reviewer 3

The reviewer commented the project is entering its final phase with testing and completion by end of third quarter 2022, so essentially ended with respect to AMR. Future work is not funded under SuperTruck II as SuperTruck 3 is an entirely new, non-diesel program. The project proposed testing beyond the program needs using routes synthesized from the NREL/Walmart data and to test in comparison to current production models rather than just the baseline 2009 model to evaluate current market relevance of the technologies.

Reviewer 4

The reviewer said plans are in place to finish the testing, and the reviewer is looking forward to seeing the results.

Reviewer 5

The reviewer remarked proposed future research is more than adequate, ensuring that the program can achieve all goals.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said the Advanced Engine and Fuel Technologies efficiency improvement objectives are relevant to this project. The weight reduction aspects of the program are relevant to the materials subprogram objectives.

Reviewer 2

I believe this project is very relevant. I think there are a number of technologies being developed here that will be important as the trucking sector transitions to ZEVs.

Reviewer 3

The reviewer said very relevant, even more so than the program team, company, and DOE are showing. So much focus on ZEVs, but if we are to deliver on GHGp2 and 3 levels for diesel trucks, these programs are hugely helpful. We should be more vocal about them.

Reviewer 4

The reviewer said yes, this program completely supports the overall VTO objectives.

Reviewer 5

The SuperTruck II program in 2016 was very relevant to DOE goals, but diesel technology improvement seems to have been eclipsed in priority by zero and near zero emission technology and market growth for commercial vehicles. However, diesels, from market demand and production rates will still be coming out in significant numbers for the next decade and will be in use longer due to their long lives. The SuperTruck II program is however showing continued improvement for diesels and may see some of the technologies in production in parallel with new zero emission and near zero emission vehicles.

The DOE has now greater investment in a broader, multi-path approach to improving commercial vehicle efficiency beyond SuperTruck II diesel research. The SuperTruck II project timing is in parallel to industry development of battery electric vehicles, hydrogen fuel cell electric vehicles, autonomous vehicles, a variety of hybrid technologies along with continued work on ICE engine refinement with multiple fuels such as renewable diesel, RNG, H_2, and other fuels to address both efficiency and reduce emissions. Infrastructure technology for these alternatives is also now a priority for DOE investment.

WHR is appearing to be not commercially viable based on conclusions from at least three of the five SuperTruck II teams. WHR may not be commercially viable in the remaining timeline of fossil fuel diesels versus zero emission and near zero emission market adoption. Aspects of the 55% BTE engine development with respect to friction reduction and coatings may be applicable to a range of engines in the near term. Aerodynamics, light weighting, and mild hybridization investigated in this project appear to be relevant to future commercial vehicles and DOE objectives. Development of new cabs and chassis have some potential to impact future designs, but they are still tied to diesel engine placement, so are less optimized to facilitate other powertrain choices.

The SuperTruck II project comparison to a 2009 Baseline has some usefulness for continuity with prior SuperTruck I programs, but is less relevant to commercialization potential of the technologies in 2022 and beyond with respect to the 3-year ROI SuperTruck II goal, as the current truck buyers are not buying 2009 trucks, but much more capable 2022 ones that have been through significant GHG 1, GHG 2 and commercial refinements in the period since 2009. These buyers also are now able to procure zero emission battery electric vehicles and other non-diesel alternatives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said the project appears it will reach completion on budget.

Reviewer 2

The reviewer said that from the information provided the resources seem sufficient.

Reviewer 3

The reviewer commented resources seem sufficient.

Reviewer 4

The reviewer remarked the project, with time extension due to COVID ramifications, is on track to completion and successfully meeting or exceeding the primary two goals without requiring additional funding from DOE. The project reported spend to date of $39 million with less than $1 million to be expended in the final period. DOE AMR reviews could benefit from standardizing AMR reporting requirements on budget, requiring spend to date, funds remaining, and additional detail to help reviewers determine resource adequacy. This could be done through a first page template.

Reviewer 5

The reviewer said it should have enough funding to complete the remaining program.

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 five reviewers evaluated this project.

Project Relevance and Resources

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

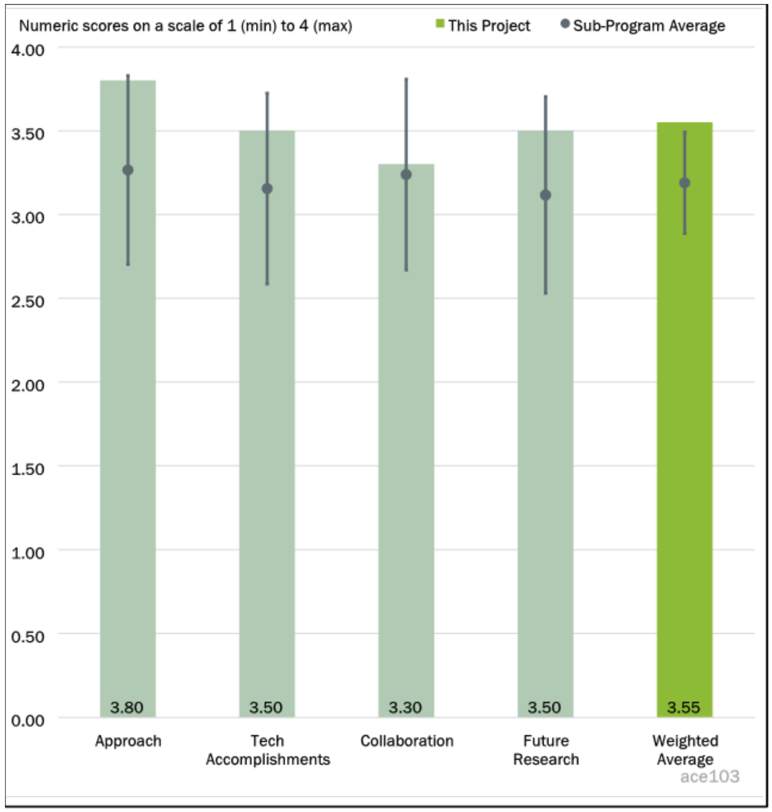

Figure 1-6 - Presentation Number: ace103 Presentation Title: Development and Demonstration of a Fuel-Efficient Class 8 Tractor and Trailer SuperTruck Principal Investigator: Russell Zukouski, Navistar

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said the approach to achieving targets for engine efficiency and freight efficiency are very comprehensive with a number of innovations such as exploring a skip fire cylinder deactivation and incorporating a full high-voltage hybrid powertrain. Good exploration of the three-dimensional (3-D) printed cylinder head. The team is broad and capable.

Reviewer 2

The reviewer remarked the project is expected to be complete as of end of June 2022. Significant efforts to complete testing by that date seem unrealistic, but if testing and reporting continue into third quarter 2022, these would not be expected to impact DOE program budgets. The project is the only one that pursued full hybridization in combination with diesel engine developments. The new vehicle cab, and other technologies were done in a timely manner and consistent with comparison to the 2009 baseline vehicle. The project has demonstrated 55% BTE engine and on track to demonstrate a 140% FTE vehicle, exceeding goals with respect to the 2009 baseline.

Reviewer 3

My understanding is the Navistar program is essentially complete and all objectives were met or exceeded. Congratulations! I very much liked that the Navistar team took on some new and innovative ideas to integrate into this project. I would have appreciated more discussion on technology commercialization and cost.

Reviewer 4

The reviewer said the team aggressively pursued the big concepts to deliver performance. Of all the programs, evidence presented showed a good approach to total cost of ownership of selected technologies.

Reviewer 5

The reviewer remarked that both the engine and vehicle programs have a clear technology roadmap to achieve the program goals.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer said congratulations are warranted on exceeding the 55% BTE target. The hybrid powertrain presents an opportunity for additional learning and data collection. Impressive integration of electric power into ICE-based powertrain. Completing a cost-benefit analysis of the hybrid system and the waste-heat recovery would be very valuable to DOE and the technical community. Ability to achieve ultralow nitrogen oxides (NO_x) would be good future target activity. The reviewer also noted great progress in weight reduction.

Reviewer 2

The project incorporates a full hybridization with 600 volt (V) systems, a significant accomplishment relevant to progress on zero and near-zero emission vehicles as well as diesels. The team produced a 61.3% aerodynamic drag improvement, 21.8% rolling resistance improvement, and weight reduction of 3,980 lb versus the 2009 baseline. The engine development demonstrated a 55% BTE engine with high flow cylinder head and other improvements.

Reviewer 3

Overall I was very impressed with Navistar team’s technical accomplishments. First and foremost, this was the only team that developed a high voltage hybrid system. This is extremely relevant to future ZEV technology so in my view this showed good forethought. I would have liked to see a more bottom-up design to the truck cab instead of just modifications to the SuperTruck I design (this is how I understood what was done). My understanding was that the 55% BTE engine would not be utilized on the demonstration vehicle. I understand that this was not a requirement of the project, but it is disappointing that it seems like none of the SuperTruck teams will be utilizing their 55% BTE engines in their vehicle demo.

Reviewer 4

Team presented sufficient information for me to evaluate as a reviewer if the necessary progress was achieved. As with all programs, the reviewer expected a better final review of cost, commercialization, and performance. The reviewer knows we do not have testing complete yet, and the team did share that they will complete all the testing and then study all concepts for commercialization potential. The reviewer would like to see that published.

Reviewer 5

The reviewer noted that significant progress has been made on the engine side to achieve 55% BTE goal. The reviewer asked what kind of engine is finally installed into the vehicle? What are the key differences between the engine dynamometer demonstrated engine and the engine that is installed in the vehicle? It seems that the WHR was not installed in the final vehicle for demonstration. Why not? Would that be because there is no space for that or just the team does not have the time and resources to make this happen? Any clarification would be helpful.

The reviewer is still curious, how would cylinder deactivation be attributed to any benefits to 55% BTE? It seems that a lot of funding or budget were relocated to something that has not been directly linked to the program goal. It is confusing if the program has really achieved 145% freight efficiency improvement shown in Slide 17 because Slide 16 still shows more vehicle testing is on the way. The reviewer requested that the team please clarify.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer remarked all partners played their role properly in this program.

Reviewer 2

The reviewer noted the project effectively engaged with fleet, suppliers and research groups to accomplish its objectives. Team partners with Navistar included Argonne National Laboratory (ANL), Lawrence Livermore National Laboratory, Bosch, TPI Composites, Dana, Borg Warner, Jacobs Vehicle Systems, Tula, and JB Hunt.

Reviewer 3

The reviewer said the team is comprehensive and made numerous contributions. The details of contributors could have been presented a little better in a tabulation because this is a specific scoring criterion.

Reviewer 4

The reviewer said it was difficult to gauge this question too well based on the presentation, and the reviewer would have appreciated more feedback from JB Hunt on the demo truck.

Reviewer 5

The reviewer noted that coordination seems strong, but more evidence of working with customers, or even industry groups, dealers, etc. who could have helped with voice of customer would have improved the project, both internally to the project and with the greater industry.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer noted the project is essentially complete as of June 2022. Future work is not funded under SuperTruck II as SuperTruck 3 is an entirely new, non-diesel program. No future work was specifically proposed, but the project alluded to future work with cylinder deactivation was on-going.

Reviewer 2

The reviewer said although the project is ended, the recommendation here is for a follow-on project conducting on-road studies of the hybrid electric vehicle (HEV) system and conducting a cost-benefit analysis of the HEV and WHR systems.

Reviewer 3

The reviewer commented it seems that the program is on the way to completion, and therefore, there is no need to have any future research proposal.

Reviewer 4

The reviewer said the plan is strong to finish the few deliverables yet to complete.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer commented yes, this program does support the overall VTO objectives.

Reviewer 2

The reviewer believed this project is very relevant, and thought the team has been very strategic to focus on the high voltage hybrid technology that will be important as the trucking sector transitions to ZEVs.

Reviewer 3

The reviewer remarked the features discovered and developed in this project will provide a significant opportunity for fuel savings and carbon dioxide (CO_2) reduction for many years while battery electric vehicle (BEV) and electric drive technology and infrastructure (including low-carbon electricity) are on a path to full readiness. Learning and manufacturing with HEV components will strengthen the supply chain base. Unfortunately, there was not yet a net-zero carbon fuel task in SuperTruck II.

Reviewer 4

The SuperTruck II program in 2016 was very relevant to DOE goals, but diesel technology improvement seems to have been eclipsed in priority by zero and near zero emission technology and market growth for commercial vehicles. However, diesels, from market demand and production rates will still be coming out in significant numbers for the next decade and will be in use longer due to their long lives. The SuperTruck II program is however showing continued improvement for diesels and may see some of the technologies in production in parallel with new zero emission and near zero emission vehicles.

The DOE has now greater investment in a broader, multi-path approach to improving commercial vehicle efficiency beyond SuperTruck II diesel research. The SuperTruck II project timing is in parallel to industry development of battery electric vehicles, hydrogen fuel cell electric vehicles, autonomous vehicles, a variety of hybrid technologies along with continued work on ICE engine refinement with multiple fuels such as renewable diesel, RNG, H_2, and other fuels to address both efficiency and reduce emissions. Infrastructure technology for these alternatives is also now a priority for DOE investment.

WHR is appearing to be not commercially viable based on conclusions from at least three of the five SuperTruck II teams. WHR may not be commercially viable in the remaining timeline of fossil fuel diesels versus zero emission and near zero emission market adoption. Aspects of the 55% BTE engine development with respect to friction reduction and coatings may be applicable to a range of engines in the near term. Aerodynamics, light weighting, and mild hybridization investigated in this project appear to be relevant to future commercial vehicles and DOE objectives. Development of new cabs and chassis have some potential to impact future designs, but they are still tied to diesel engine placement, so are less optimized to facilitate other powertrain choices.

The SuperTruck II project comparison to a 2009 Baseline has some usefulness for continuity with prior SuperTruck I programs,but is less relevant to commercialization potential of the technologies in 2022 and beyond with respect to the 3-year ROI SuperTruck II goal, as the current truck buyers are not buying 2009 trucks, but much more capable 2022 ones that have been through significant GHG 1, GHG 2 and commercial refinements in the period since 2009. These buyers also are now able to procure zero emission battery electric vehicles and other non-diesel alternatives.

Reviewer 5

The reviewer remarked given fuel costs and abilities to meet GHGp2 and p3 regulations this program is more relevant than the awardees and even the DOE seem to state publicly. So much focus on ZEVs and this program has been critical for tech advancement on diesel powered long haul trucks.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer's understanding is the project is complete and the resources were sufficient.

Reviewer 2

The reviewer said resources seem sufficient.

Reviewer 3

The reviewer said the team should have enough funding the complete the program objectives.

Reviewer 4

The reviewer remarked the project is at conclusion, and had no comments on this question.

Reviewer 5

The reviewer remarked the project with a time extension due to COVID ramifications, is on track to complete and successfully meeting or exceeding the primary two goals without requiring additional funding from the DOE. The project expects to be complete by June 2022. DOE AMR reviews could benefit from standardizing AMR reporting requirements on budget, requiring spend to date, funds remaining, and additional detail to help reviewers determine resource adequacy. This could be done through a first page template.

Presentation Number: ace124
Presentation Title: SuperTruck 2 – PACCAR
Principal Investigator: Maarten Meijer, PACCAR

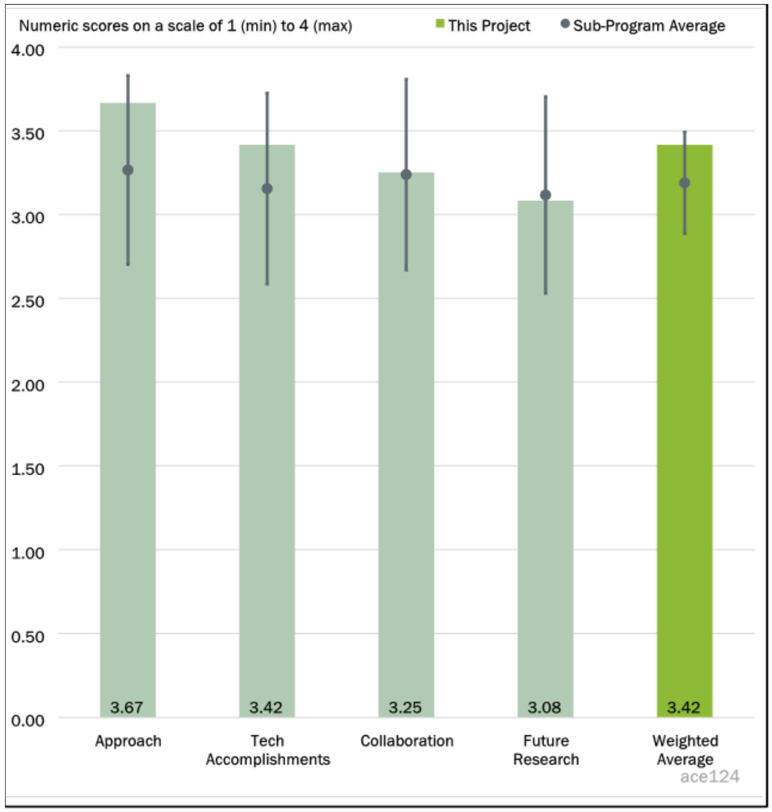

Figure 1-7 - Presentation Number: ace124 Presentation Title: SuperTruck 2 – PACCAR Principal Investigator: Maarten Meijer, PACCAR

Presenter

Martin Meijer, PACCAR

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 17% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

In this reviewer's view the PACCAR presentation was the most impressive of the 5 SuperTruck presentations—even though PACCAR started one year later than the other teams. The approach seems to be both practical as well as innovative. The reviewer very much appreciated the wide range of technologies that the team appears will be ready to commercialize in 2024-2027 aided by this project.

Reviewer 2

The reviewer said the approach to technical barriers is thorough with little room for improvement within the Funding Opportunity Announcement (FOA) requirements. The reviewer appreciates the assessment of the gasoline compression ignition engine and thoughtful reasons for not continuing as a prime path. Perhaps it would be reconsidered in a program that included net zero carbon fuels. The team is very comprehensive.

Reviewer 3

The reviewer said improved efficiency engine, weight reduction, and aerodynamics improvements used in combination to achieve 170% freight efficiency improvement. These elements are nicely integrated into the project. The reviewer noted a well-designed approach.

Reviewer 4

The reviewer noted the project is expected to complete in December 2023, starting a year later than the other SuperTruck II teams. The project has made significant progress with developing an all-new vehicle capable of exceeding the goal of 120% FTE and towards an engine capable of 55% BTE. The project evaluated the potential for gasoline compression technology and determined NO_x emissions were unacceptable and chose not to pursue that technology. The reviewer said the project is working with Cummins on adapting a WHR system tailored to the PACCAR engine. This approach is low risk. The choice of a 4x2 configuration with sleeper for the demonstrator is somewhat contrary to typical 4x2 market which tends to be day cabs. In light of the challenges due to COVID and worldwide supply chain issues, the project has been executed well to date.

Reviewer 5

The reviewer said the team presented a solid plan to complete the build and testing of the frozen design. The slides and presentation were clear on the concepts selected and plans going forward.

Reviewer 6

The reviewer said the team has all pieces required to build the program, which could achieve the goals for both of engine and vehicle programs. However, the approaches seem to be too aggressive because of lacking prior experience, and putting all bets into one basket in the hope that one final engine demonstration can meet the program 55% BTE goal.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer said progress is on a good path of designing and building components and prototypes. The project has another year to go so the team does not have engine efficiency demonstrated yet. The achievement of ultralow NO_x is commendable, because this was not a firm requirement in the FOA.

Reviewer 2

The reviewer said that for the engine efficiency demo, all components completed proof of concept and final demo build started. For the freight efficiency demo, a 48V hybrid battery system, e-HVAC, e-heater, dual loop cooling, and controls were completed and being built into the demo truck.

Reviewer 3

The reviewer said this is a complex all-new chassis and cab design with a center steer driver position. The vehicle is expected to be ultra-low NO_x 2027 compliant. The design incorporates mild hybridization with 48V systems replacing belt driven engine accessories. The aerodynamic refinement is significant for both the tractor and trailer as a system, including real world operational details such as accommodating for sliding trailer tandems and modeling aero loads from vehicles passing in opposite directions on two lane roads. The all-new chassis design is estimated to achieve a 28% weight reduction.

Reviewer 4

The reviewer said there were number of accomplishments that were very notable, including weight reduction on the tractor/trailer. New, bottoms-up aerodynamic cab design, and the team even demonstrated an ultra-low NO_x after treatment system. The reviewer's understanding was that the 55% BTE engine will not be utilized on the demonstration vehicle mainly due to WHR-related packaging constraints, and the reviewer understands that this was not a requirement of the project, but it is disappointing that it seems like none of the SuperTruck teams will be utilizing their 55% BTE engines in their vehicle demo.

Reviewer 5

The reviewer said good progress was made in this critical phase of the program, and the reviewer would like to see more data on cost relative to the requirement of commercialization of all selected systems. This seems to be missing from all SuperTruck II programs.

Reviewer 6

The reviewer said a lot of progress has been made on the vehicle side. Although it sounds to be ready to go for the engine, there are still many unknowns about whether the engine program can achieve the program goal. It seems that PACCAR has tremendous confidence that one set of engine hardware can achieve the program goal, but in reality, there could have been many more iterations to finalize the engine hardware and its key components. We will see.

The reviewer said it is confusing and not helpful at all when the improvements on many key components, such as powertrain efficiency (Slide 12) and freight efficiency (Slide 14), are shown as a percentage. At a minimum, in order to help the reader/reviewer understand the impacts of the improvements, some tangible values, such as weight reduction in absolute numbers, should be provided, just like the competitors.

The reviewer said it seems that the WHR was not installed in the final vehicle demonstration. Can the team clarify? The concern is that PACCAR jumped into the program late. It utilized a WHR from Cummins, which would certainly make a tremendous shortcut. Also, PACCAR has no experience on how the WHR can be installed into vehicle from SuperTruck I program, because they were not part of the program.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer remarked the project effectively engaged with fleet, suppliers and research groups to accomplish its objectives. Primary partners with Kenworth are Eaton, AVL, University of Washington, NREL, Ohio State University, DAF, Cummins, and the PACCAR Technical Center. Others, including fleets, were engaged in review of concepts. The reviewer noted the project tapped a wide range of expertise in developing the system

Reviewer 2

The reviewer said explanation of team members and roles in tabulation is instructive.

Reviewer 3

The reviewer noted that Slide 21 nicely lays out the collaborators and their areas of contribution. It would have been nice (maybe in backup slides) to identify some specifics of their contributions, as that is not detailed in the presentation.

Reviewer 4

The reviewer said all partners play their roles in the program.

Reviewer 5

The reviewer found this question a bit difficult to fully judge based on the materials that were presented. The discussions about the collaboration were limited. That being said, the slide that shows the different expertise that the partners are bringing to the project was very helpful. The reviewer acknowledged there was some mention about getting driver feedback on the cab design, but it also might be helpful to bring in a fleet into more of a partnership role.

Reviewer 6

Collaboration seems to be strong particularly with Cummins after two SuperTruck programs should be expected. The team discussed a Customer Council, but the reviewer continues to see a lack of sharing of information from voice of customer efforts. In all DOE AMRs on this program, it has been shared that we have that collaboration, just trust us, but the AMR is an excellent opportunity to share key customer demands and how the designs meet them. Even sharing areas of concern. The reviewer is disappointed to continue to not see this.

Question 4: Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1

The reviewer said plans are in place to finalize the program, and the reviewer is looking forward to another review next year.

Reviewer 2

The reviewer said it would be beneficial to produce vehicle CO_2 and fuel consumption numbers in simulation over the Federal Test cycles. Similarly, could engine $bsCO_2$ be shown over standard Supplemental Emissions Test (SET) procedure. It was not clear from the slides whether the WHR system was going to be used in the vehicle demo for freight efficiency. The cost-benefit impact of the 48V mild HEV will be interesting to see. Good luck on completing project.

Reviewer 3

The reviewer said everything looks on track to demonstrate the engine and freight efficiency goals within budget and the current timeline (the reviewer believed there was a COVID extension?)

Reviewer 4

The reviewer remarked the project is in budget period 4 of 5, due to complete at end of 2023. The project reported that completing the 55% BTE engine demo and completing build of the 175% FTE demonstrator vehicle remain to be done. These are the two core deliverables for the program. No additional research areas were identified.

Reviewer 5

The future research listed is fine, but very scant details were given so the reviewer is not quite sure how to judge this with any detail besides understanding that the next step is demoing the engine and the truck.

Reviewer 6

The reviewer said just a few words for the proposed future research of both engine and vehicle programs were way too simplified. Considering that no demonstration has been made in the middle of engine dynamometer tests, it would be too risky to believe that one shot with the final engine assembling and running can meet the program goal for 55% BTE.

Question 5: Relevance: Does the project support the overall VTO subprogram objectives?

Reviewer 1

The reviewer said the technology discovered and developed here will have benefits toward reduction of CO2 and fuel consumption for many years in this difficult-to-decarbonize sector of freight movement. In follow-on efforts, if possible, the use and impact of low-carbon fuels could be evaluated.

Reviewer 2

The reviewer remarked Advanced Engine and Fuel Technologies subprogram goals of increased efficiency are relevant. The Materials sub program goal is addressed in the weight reduction aspects of this project.

Reviewer 3

The reviewer believed this project is very relevant, and thought the PACCAR team has been very strategic to focus on many technologies that will be important as the trucking sector transitions to ZEVs.

Reviewer 4

The SuperTruck II program in 2016 was very relevant to DOE goals, but diesel technology improvement seems to have been eclipsed in priority by zero and near zero emission technology and market growth for commercial vehicles. However, diesels, from market demand and production rates will still be coming out in significant numbers for the next decade and will be in use longer due to their long lives. The SuperTruck II program is however showing continued improvement for diesels and may see some of the technologies in production in parallel with new zero emission and near zero emission vehicles.

The DOE has now greater investment in a broader, multi-path approach to improving commercial vehicle efficiency beyond SuperTruck II diesel research. The SuperTruck II project timing is in parallel to industry development of battery electric vehicles, hydrogen fuel cell electric vehicles, autonomous vehicles, a variety of hybrid technologies along with continued work on ICE engine refinement with multiple fuels such as renewable diesel, RNG, H_2, and other fuels to address both efficiency and reduce emissions. Infrastructure technology for these alternatives is also now a priority for DOE investment.

WHR is appearing to be not commercially viable based on conclusions from at least three of the five SuperTruck II teams. WHR may not be commercially viable in the remaining timeline of fossil fuel diesels versus zero emission and near zero emission market adoption. Aspects of the 55% BTE engine development with respect to friction reduction and coatings may be applicable to a range of engines in the near term. Aerodynamics, light weighting, and mild hybridization investigated in this project appear to be relevant to future commercial vehicles and DOE objectives. Development of new cabs and chassis have some potential to impact future designs, but they are still tied to diesel engine placement, so are less optimized to facilitate other powertrain choices.

The SuperTruck II project comparison to a 2009 Baseline has some usefulness for continuity with prior SuperTruck I programs, but is less relevant to commercialization potential of the technologies in 2022 and beyond with respect to the 3-year ROI SuperTruck II goal, as the current truck buyers are not buying 2009 trucks, but much more capable 2022 ones that have been through significant GHG 1, GHG 2 and commercial refinements in the period since 2009. These buyers also are now able to procure zero emission battery electric vehicles and other non-diesel alternatives.

Reviewer 5

The reviewer said is more relevant than the presenters and the DOE seem to show. ZEVs are coming fast, but we need this research to be able to deliver on GHGp2 and then GHGp3 diesel trucks.

Reviewer 6

The reviewer said yes, this program does support the overall VTO objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said under the present scope, the resources appear to have been adequate. If the scope were expanded to net-zero carbon fuels, additional funds would be needed.

Reviewer 2

The reviewer said resources may be sufficient, but with the current progress without any prior experience, the project may not have enough funding the complete the program, specifically on the engine side, which may require a lot of tuning on the final hardware and calibration packages. We will see.

Reviewer 3

The reviewer said from the information provided the resources seem sufficient.

Reviewer 4

The reviewer said resources seem sufficient.

Reviewer 5

The budget shown on Slide 2 says FY 2022 Funding: $34.7 million, and the reviewer assumed this is the accumulative budget over the life of the project to date, as that would be an excessive one-year budget number!

Reviewer 6

The reviewer noted the project started later than the other SuperTruck II projects. Budget spent to date was not reported, however the project did not identify any risk with budgets in the review, and estimated FY 2022 funding was $34.7 million of the planned $40 million budget, so this year represent significant spending, and the project also reported they were 75% complete at the AMR. The reviewer said DOE AMR reviews could benefit from standardizing AMR reporting requirements on budget, requiring spend to date, funds remaining, and additional detail to help reviewers determine resource adequacy. This could be done through a first page template.

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 five reviewers evaluated this project.

Project Relevance and Resources

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

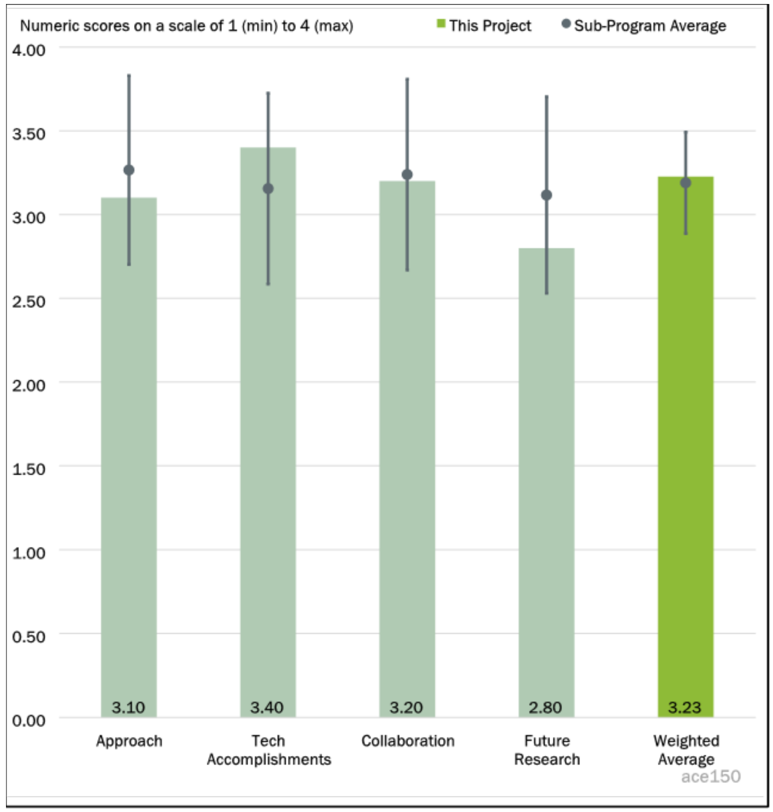

Figure 1-8 - Presentation Number: ace150 Presentation Title: Enabling Low-Temperature Plasma (LTP) Ignition Technologies for Multi-Mode Engines through the Development of a Validated High-Fidelity LTP Model for Predictive Simulation Tools Principal Investigator: Nick Tsolas, Auburn University

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said good combination of simulation and experiment.

Reviewer 2

The reviewer remarked the approach was generally well designed. The reviewer tends to agree with one reviewer's comment that the temperature and pressure are not representative of engine-relevant conditions. It will hard to directly plug in the developed tools in engine applications.

Reviewer 3

The reviewer said the PIs adequately addressed technical barriers, and the timeline is reasonably planned. As will be discussed later though, one has to wonder if there is not a disconnect between the planned work and the needs of industry to actually apply actual engine development.

Reviewer 4

The reviewer said this project concerns developing low temperature plasma (LTP) ignitors to facilitate lean burn and exhaust gas recirculation (EGR) controls. It focuses on barriers the PIs believe must be overcome to enable plasma ignition to operate ICEs such as the connection between plasma-specific kinetics and the combustion kinetics which sustain operation of the engine; and validation of the kinetics. The PIs intend that their results will provide higher fidelity modeling of performance using commercial codes such as from Convergent Science.

The reviewer said the approach is framed around fundamental studies on experimental designs that are principally the plasma flow reactor (PFR) and the ignition test vessel. In the PFR, species are detected at various times as the gases flow through the reactor and from this information an attempt is made to determine the reaction pathways, for iso-octane and ethanol as the two fuels of interest.

The reviewer posed several questions should be addressed.

- Iso-octane and ethanol are both liquid under standard conditions. Both are apparently pre-vaporized for the PFR and ignition tests. How does elimination of the liquid phase effect the results? Fuel is injected as a liquid into an ICE. Is there any coupling between droplets in spray injection and the chemistry of ignition (some literature suggests that there is a connection that should essentially be avoided by obtaining data under pre-vaporization (i.e., gas phase) conditions)?

- The engine environment is quite complex with turbulence, swirl, and gas phase unsteadiness. What assurances are there that the results of this study will be applicable to the more complex environment of an engine? Are the mechanisms broadly applicable? Mechanisms need to be validated, for example with Convergence simulations, and adjusted to improve the agreement with certain key metrics of the engine performance. The same holds true for any reduced mechanism developed. The result will likely be applicable to the specific engine being considered.

- How many reactions and species were there for the iso-octane and ethanol kinetic mechanisms. What guided the choice of the mechanism chosen?

Reviewer 5

The reviewer said the approach to develop a chemical kinetic mechanism for LTP kinetics is reasonable with Auburn focusing on developing the mechanism, Sandia National Laboratories (SNL) measuring the ignition characteristics and University of Texas/ANL supporting the integration into the exascale software. For teams such as this without any specific industry partners, the reviewer would recommend VTO to setup an industry advisory board that can provide periodic comments on the team's approach. The automotive industry is undergoing an inflection point right now and hence continuous input from industry stakeholders is necessary.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer said good progress and results were shown.

Reviewer 2

The reviewer commented the technical progress looks good. Again, the pyrolysis modeling comparing to a detailed iso-octane mech is probably fine at 1 bar, and will become an issue at elevated engine conditions. It is a good effort to have the model available in a commercial code for engine combustion applications.

Reviewer 3

The reviewer remarked the PIs have done a very good job keeping the work on schedule as evidenced by the Milestone chart presented. The team presented many detailed results. Can the PIs please comment on the prospect that plasma igniters will actually be implemented in commercial vehicles. The concept has been known for some time now.

Reviewer 4

The reviewer said the team has completed 45% of the proposed work, which is only slightly behind the schedule.

Reviewer 5

The reviewer said technical accomplishments of the project are satisfactory. I understand that we have to walk before running but I believe multi-component fuels should also be investigated (at least primary reference fuels [PRF] and TRF fuels). Sensitivity and validation at engine relevant pressures should be conducted. Much of the work has been at 1-2 atm. The reviewer wonders if constant volume chamber experiments are necessary to be undertaken for mechanism validation under higher pressures.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said collaboration between the four PIs is quite good with good delineation between the different facilities.

Reviewer 2

It may be outside of the scope of the project, but the reviewer thinks there would be value in including an ICE OEM.

Reviewer 3

The reviewer noted that the project team consists of four groups, with Auburn in charge of the flow reactor and development of the kinetic mechanisms, SNL measuring fuel ignition characteristics, University of Texas performing ignition simulations, and ANL in charge of the Converge computational fluid dynamics (CFD) that uses the plasma kinetics to evaluate its performance. It could enhance the program to include an OEM on the team and show a stronger link with results of the present.

Reviewer 4

The reviewer said collaboration within the team is really good. The reviewer referenced prior comments about an industry advisory board for reviewing this project periodically will help.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The future work is noted for oxygenated and sustainable fuels and developing skeletal mechanisms for them. The principal investigator (PI) mentions methanol in this regard. It was not clear if the team envisions methanol by itself or as a blending agent to a petroleum fuel. If the latter, a surrogate-based approach would presumably be needed but was not noted in the future plans.

Reviewer 2

The reviewer said that in the future work, the PIs propose focusing mechanism development on EGR blends and oxygenates, inclusion of turbulence, turbulent mixing, etc. in numerical work, and considering lumping strategies in skeletal mechanism development, all of which will be very helpful for achieving the main targets. However, as in many DOE project, there is a significant disconnect between this research and the practical needs of engine developers—and the reviewer suggests some consideration of the following:

- The 3-D simulation in AMRex takes 3600 cores, 200 M cells and AMR resolution of O(1 mm), which is not feasible for industrial ICEs. Could the PIs provide a reasonable scheme or solution that is more practical in simulating LTP ignitors in real engines?
- The pressure range in SNL LTP ignition experiment is 1 - 4 bar, which is much lower than working pressure of OEM ICEs. It will be more useful if SNL can perform experiments at higher pressure with simulation work to validate the selected kinetic mechanism at these elevated pressure conditions.

Reviewer 3

The reviewer suggests considering semi-coupling method for the skeletal mechanism development in addition to the DRGEP approach.

Reviewer 4

The reviewer sees in the comments that contact has been made with Convergent Science, to incorporate the findings from this project. Hopefully those discussions are fruitful.

Reviewer 5

The reviewer said it was nnclear why methanol + EGR (understand it is the simplest oxygenate fuel) was chosen as its applications are limited. Also, ethanol+EGR should be validated. Plans could include methane air, propane air and PRF for future work.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said LTP is a useful enabler of efficiency and we currently do not have much understanding of the kinetics. This project is a step in the right direction for understanding the science.

Reviewer 2

The reviewer said yes, the project is relevant. If successful, this project will help to develop new LTP ignition technology useful for high-efficiency, next-generation ICEs.

Reviewer 3

The reviewer noted the outcome of this work is anticipated to improve the accuracy of commercial engine solvers such as from Convergence Science, Inc which the ANL partner is developing. The goal is to reduce emissions and improve engine efficiency. The PIs should discuss specific links of their work to their claim of lowering emissions and engine efficiency.

Reviewer 4

The reviewer remarked there is potential for LTP engine applications and it will be good to have a tool to facilitate exploration of the technology.

Reviewer 5

The reviewer said it is responsive to the overall VTO objectives, but questioned if the lack of accurate/predictive models is why LTP igniters have yet been adopted by industry.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said resources are appropriate.

Reviewer 2

The reviewer said resources are deemed sufficient.

Reviewer 3

The reviewer said resources of the project appear sufficient to achieve stated goals.

Reviewer 4

The reviewer remarked the resources seem adequate, though without more details (e.g., overhead rate, scientist and technician salaries, equipment costs, etc.) beyond the bottom-line costs for the project provided in the presentation, it is not possible to adequately score this category. An ultimate judgement would have to come from a cost/benefit analysis based on DOE’s investment relative to the commercialization potential of what the PIs are pursuing.

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

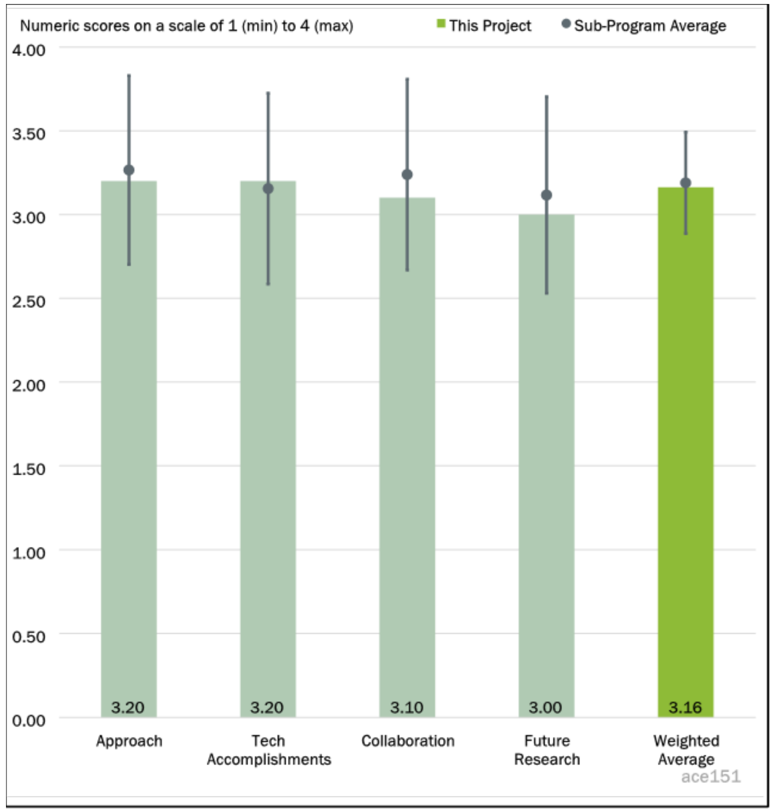

Figure 1-9 - Presentation Number: ace151 Presentation Title: Hierarchically Informed Engineering Models for Predictive Modeling of Turbulent Premixed Flame Propagation in Pre-Chamber Turbulent Jet Ignition Principal Investigator: Haifeng Wang, Purdue University

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said prechamber technology is an enabling technology to achieve better engine performance. One of the challenges is to accurately predict the combustion jet from the prechamber to the main chamber. This certainly justified the project. The approach is sound by going from large-eddy simulation (LES) to Reynolds-averaged Navier-Stokes (RANS) to develop the methodology and evaluate the applicability of the model for engine applications.

Reviewer 2

The reviewer remarked pre-chamber ignition will play a substantial role in achieving the performance constraints, especially for high-horsepower engines that seek to explore the lean-burn benefits while employing low carbon fuels, H_2, or its blend with natural gas. Modeling the pre-chamber combustion is complicated because of the challenges posed by three parameters—flow field and the associated mixing, spark ignition, and the subsequent flame propagation. The current work has effectively addressed all these challenges except for the spark ignition—would be interested in seeing more work in this area or discussion of how challenge in this area will be resolved.

The reviewer noted that the report shows steady progress made over budget periods 1 and 2. The objectives planned for the budget period 3 look a tad overwhelming (also as stated in question 8) but they will offer a good conclusion to this project. The project is well designed, and the timelines are reasonably planned. Concerns with the technical nature of the work are explained in the following comments.

Reviewer 3

The reviewer detailed that this project concerns improving the predictive accuracy and efficiency of turbulent combustion sub-models being used in simulating premixed flame propagation in various engine configurations for off-road, marine, and rail systems. More specifically it involves examining the potential of pre-chamber ignition engine fueled by H_2 off-road, rail engines and possibly marine and on-road engines. It appears that H_2 is the fuel of interest. The emphasis is on developing accurate and efficient models for turbulent flame propagation initiated by a pre-chamber turbulent jet ignition source. Turbulent submodels are being examined for simulating flame propagation initiated by turbulent jet ignition.

In the turbulent jet flame images shown are these for H_2?

The reviewer detailed three project objectives: examine properties of tubulent premixed flames using direct numerical simulations (DNS); develop a LES for turbulent jet ignition (TJI); and using machine learning (ML) to develop Reynolds averaged model based on LES. The DNS is considered to provide the bases for informing a reduced-order LES model for practical pre-chamber jet ignition. Engineering models for turbulent jet ignition are being examined and validated, then ultimately deployed.

The reviewer asked the team please provide some discussion of precisely what engine configurations are envisioned for applying results of the study.

The reviewer noted the approach is based on three levels of modeling, DNS, LES, and RANS. Is this necessary? Could just the DNS and, say, LES be examined without RANS? How is the computational time effected from the three approaches? Data are provided through SNL premixed jet flame studies along with the Purdue TIJ model and ANL's single cylinder engine data.

The reviewer was not clear how the engineering models for TJI are being validated. Is it a straight comparison between experiments and modeling? What is the strategy for addressing discrepancies between experiment and simulation in the validation process? How will the results and models be translated to the engine platforms envisioned (marine, rail, off-road)?

Reviewer 4

The reviewer noted that though TJI is being used at least in demonstrator engines, the science behind is not all clear. Hence, this work assists in understanding the science behind TJI and building robust models to mimic experimental results. The correlation between DNS and LES and a further development of RANS model for TJI will be a great contribution.

Reviewer 5

The reviewer said good approach. It would be better if more highly stressed conditions were included, such as operation at cold temperatures, light loads with high residuals, and lambda=1.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer commented the team has performed very well. The ML model predictions look promising. What is a bit disconcerting is the results from the unfueled prechamber. The same model is unable to do good predictions of unfueled pre-chamber spark ignition. The team needs to look into this issue and address the model deficiencies. In general, the reviewer feels that the model predictions of pressure and heat release are sluggish compared to experiments and this most probably has to do with the turbulent chemistry interaction (eddy dissipation model?).

Reviewer 2

The reviewer said progress is good with demonstrated performance of the model at both laboratory and engine applications. The ML-assisted mixing model is interesting; however, it was more expensive computationally than the traditional mixing models, which is a bit unexpected. The reviewer remarked one would think the ML will significantly reduce the cost by pre-training datasets and ignoring physics.

Reviewer 3

The reviewer said accomplishments in the reporting period show that the project has hit the milestones, or on schedule to do so. The mixing model has been tested, ANL has carried out simulations to benchmark results from its single cylinder engine, and ML has assisted in the modeling of various targeted product species.

The experimental systems employed are far removed from the engine design; what assurances are there that the models and kinetics developed will be applicable to the various engine platforms that are envisioned?

The global chemistry for methane is noted. It appears to be single step, but it was not clear. If it is single step, is that realistic?

Reviewer 4

The reviewer asked what is the explanation (and solution) for the needed turbulence forcing? This needs to be predictive.

Reviewer 5

The reviewer remarked the current report has included promising validations for the two models developed—ML assisted mixing model, and ML assisted combustion model. However, the results shown are not compelling enough to address the project goal stated by the author in Slide 3—"Significantly 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." The report does not have statements/results that show a 'significant' improvement in the predictive accuracy leading to the following questions: Significant improvement in the predictive accuracy compared to what? Is the author referring to the RANS-based modeling framework that employs combustion models such as a detailed-chemistry-kinetics-model or a flamelet-based G-Equation model that needs improvement?

The reviewer noted it is difficult to rate the technical relevance and progress of the current work without the following information: What are the challenges of the existing (or as the author calls it—traditional) modeling strategies for capturing pre-chamber performance? Quantify the improvements offered by the new models. The author has shown a comparison of the traditional versus machine-learning models in Slide 9, which shows a reduction in the grid dependency. However, just one parameter does not explain if the new models offered a "significant improvement."

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer remarked good collaboration between team partners, and the team will benefit from an industry advisory committee for guidance and direction.

Reviewer 2

The report elucidates the collaboration between national labs (ANL and SNL), universities (Purdue), and industry (Convergent Science Inc.). The sub-models developed by Purdue are (or will be) validated against the experimental data from Argonne pre-chamber equipped single-cylinder engine, Purdue TJI rig, and the DNS data from SNL. The model successfully validated is being implemented to Converge via user defined functions. The current collaborative structure is more than enough for the successful completion of this project, meaning that additional collaborations may not be required.

Reviewer 3

The reviewer noted that the main partners are Purdue and ANL, and the SNL role is unclear. It is noted that regarding some testing and data collection are being pursued at SNL, whose role seems to involve '…premixed jet flame DNS case'. What is the 'testing' and 'data collection? A budget component for SNL does not seem to be included. NREL is also noted as a collaborator. What is their role?

Reviewer 4

The reviewer said it is good to see the collaboration with SNL/Zhejiang Uni/University of New South Wales. It will be good to briefly outline the collaboration. The reviewer noted that certainly, it is very helpful to have ANL validate the engine applications. However, it is missing a real industry input to get the feedback of the model performance in real industry usages.

Reviewer 5

The reviewer said it is unclear how the other two universities are contributing. The project would benefit from the involvement of an OEM. The reviewer would not wait until you are done to involve an OEM.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said proposed future work is satisfactory.

Reviewer 2

The reviewer said future work is to include the following: developing an LES model for the entire cycle of TJI combustion; validating the model using data from the Purdue TJI experimental rig; testing the RANS model for TJI; and incorporating the Purdue model into the Converge code. The reviewer said the above is reasonable. A natural gas engine is noted; some consideration of how results from the Purdue rig would be applicable to off-road natural gas engines would be appreciated.

Reviewer 3

The reviewer remarked the authors have clearly defined the future work for the budget period 3. The future work includes interesting topics such as development and validation of a high fidelity LES model for TJI combustion; development and validation of a data-driven RANS model for TJI combustion; implementing these models into the commercial tool Converge. The reviewer remarked the number of action items seems overwhelming to be completed in budget period 3. However, there is not enough information in the current report to check if the future work will achieve the proposed target, which the author states as "significant improvement from the existing modeling process." The reviewer referenced comments provided in Question 4.

Reviewer 4

For budget period 2, the reviewer encourages the PI to find another set of TJI case to validate in addition to the one at Purdue. The reason is that there are many uncertainties in the boundary conditions of the Purdue case. Not sure how much one would get to validate the model. A more recent and carefully tuned TJI case might be helpful to get the project team an conclusion.

For budget period 3, the reviewer suggests focusing on reducing computational cost of the RANS model and have the model evaluated in an industry setting.

Reviewer 5

The reviewer remarked the project would be more valuable if the resulting model/process was proven to be predictive under more operating conditions—especially where issues are likely to exist (e.g., cold, EGR-dilute).

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer commented yes, understanding the fundamentals of TJI is extremely critical and this project is attempting it. Very impressed with the work accomplished in this project.

Reviewer 2

The reviewer said yes, prechamber as an enabling technology is very relevant to the VTO platform, now and in the future off-road applications.

Reviewer 3

The reviewer said that TJI still has promise, and supporting tools are worthy of further development.

Reviewer 4

The reviewer said the project is relevant from a broad perspective, and that a closer link of the ANL engine test facility to the types of engines typical of off-road should be established.

Reviewer 5

The reviewer remarked the project is highly relevant. Pre-chambers will be an essential component for the spark-assisted low-carbon fuels or H_2 fuels and its blends, particularly for the high horsepower applications. Pre-chambers are already quite effectively used in natural gas high-horsepower engines. Hence, developing a sound understanding of its combustion characteristics is important to improving its design to overcome challenges such as pre-ignition, spark-plug life, etc. However, an important concern with the current work is the combustion modeling strategy. The reviewer said the ML-assisted combustion modeling developed by the author is based purely on flame propagation. There is no physics (or statistical component) in the model that accounts for auto-ignition. As a result, pre-ignition in the pre-chamber will not be captured. With the traditional modeling approach such as the SAGE detailed-chemistry-model in Converge, both the flame propagation and auto-ignition characteristics would be effectively captured. The reviewer noted that this observation again leads back to questioning the project goal stated by the author that says “Significantly 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”.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer commented spending is appropriate to the activities proposed, and that resources are deemed sufficient.

Reviewer 2

The reviewer said resources are sufficient for the proposed work.

Reviewer 3

The reviewer remarked the project has all the essential resources for its completion. Resources such as experimental facilities or computational clusters will not be the bottleneck for timely completion. The primary concern is if the author included too many action items in his future plans for the budget period 3, also as stated in question 8.

Reviewer 4

The reviewer said that resources seem adequate, though without more details (e.g., overhead rate, scientist and technician salaries, equipment costs, etc.) beyond the bottom-line costs for the project provided in the presentation, it is not possible to adequately score this category. An ultimate judgement of costs come from a cost/benefit analysis based on what the project is intended to accomplish. The SNL role was not clear in the budget.

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

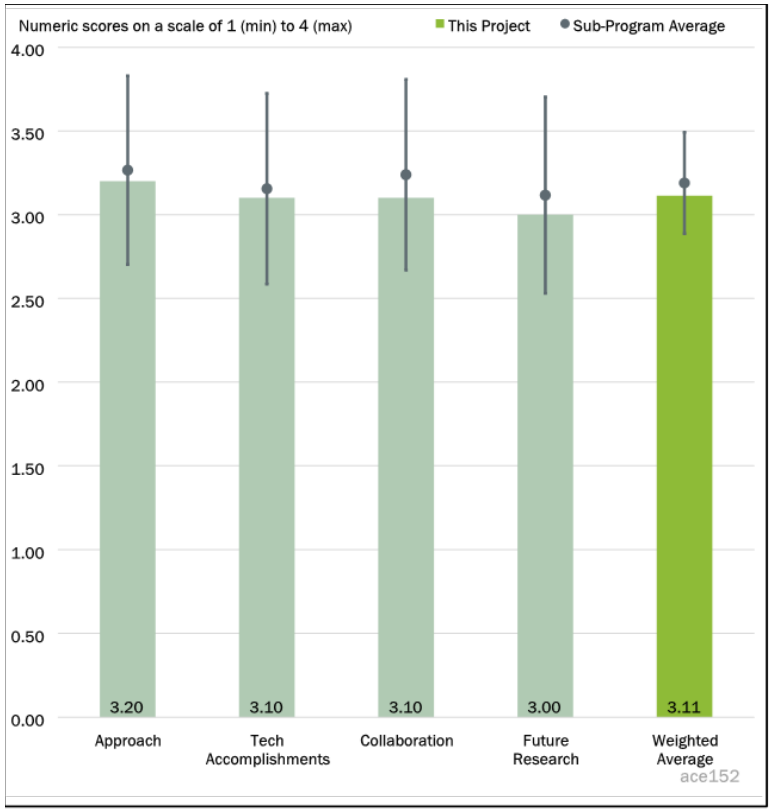

Figure 1-10 - Presentation Number: ace152 Presentation Title: Development of High-Fidelity and Efficient Modeling Capabilities for Enabling Co-Optimization of Fuels and Multi-Mode Engines Principal Investigator: Matthias Ihme, Stanford University

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer noted that this project is conducted separately by three research groups:

- Stanford applied LES modeling to low-T chemistry’s impact on rapid compression machine (RCM) ignition behavior and to spray combustion through duct fuel injection. The presentation did not explain how the study is relevant to the main goal of the project, i.e., developing high-fidelity and efficient models, and what fundamental improvement the work has been introduced.
- University of Connecticut (UCONN) addressed the fundamentally challenging issue during application of non-equilibrium high-energy plasma ignition chemistry in engine simulation. With the help of ML technique, the UCONN group proposed to train the Gaussian progress regression model under the ML framework, thus allowing the stiffness of non-equilibrium high-energy plasma ignition chemistry to be overcome during plasma-relevant engine combustion simulations.
- ANL implemented an effective Enrichment Wall model to treat the high-order near-wall flow simulation—an important step for improving wall heat transfer prediction in engine simulation. In parallel, the ANL group applied DNS to address triple flame formation in the initial flame kernel development in PFS-assisted SACI engine.

The reviewer noted the project started in 2019, so it is 75% complete in terms of project time. The three research groups have addressed most of the barriers listed but focused on different tasks separately. The project seems well balanced, and its execution is reasonably conducted.

Reviewer 2

The reviewer said the project was well designed to target the technical barriers in modeling engine combustions. These technical barriers are not just for multi-mode combustion, could also for gas engine applications.

Reviewer 3

The reviewer is looking forward to multi-mode simulation results to show exactly the level of improvement made in engine-relevant terms.

Reviewer 4

The reviewer said overall, the work product of this project is really good considering the dollars invested in this project by DOE. Improvement of physical submodels and numerical algorithms is necessary to enable co-optimization of fuels and engines.

Reviewer 5

The reviewer commented the project concerns extending lean combustion to intermediate conditions, investigating new ignition systems, and modeling multimode combustion and emissions including piston geometry effects. The approach is framed around four tasks that include models for combustion regimes, plasma ignition modeling, prediction of heat transfer within ICEs, and simulations on an exascale platform. Model validation is to come from DNS and experimental data. Submodels are indicated as being integrated into engine simulation codes.

The reviewer asked the team to please discuss where the PIs feel that RCM data will fit into the operation of an ICE. Do the PIs anticipate that ignition delay in an RCM will be the same as in an ICE? The reviewer noted there are many iso-octane mechanisms. Some elaboration of the need for the one used here would help. Are the RCM data used in any way to inform the combustion chemistry? The reviewer said the results presented showed how temperature is influenced by the number of pulses; please comment on the pulse duration and its relationship to peak power delivered compared to conventional spark ignition. If simulations have not been carried out on these aspects, the reviewer recommends that they be done. How do the results of Task 2 contribute to the potential for OEMs to adopt plasma ignition? Though plamsa ignition is an interesting and emerging concept the prospects for its incorporation into OEM manufacturer product lines is uncertain. The reviewer said this is one of the reasons that an OEM partner would help the project.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer noted that the team identified the huge uncertainty of low-temperature chemistries. This may suggest that a semi-coupling chemistry is the way to deal with chemistry-related concerns, i.e., proper tailoring or tuning. Very good progress was made at UCONN and ANL.

Reviewer 2

The reviewer said that in general, the project has progressed at a pace matching the original project plan. However, it is unclear what Stanford's Pareto-efficient combustion (PEC)-efficient combustion framework is and how much Stanford has followed its originally proposed plan.

Reviewer 3

The reviewer noted that a lot of progress has been made on the four tasks of the project. Impressive results for the MM engine simulations. The reviewer posed some comments to consider:

- There seem to be some differences between the LES and experimental data shown in the multimode combustion modeling. Is it due to the kinetic mechanism? It would be helpful to note the impact that thermal and transport properties have on the simulations.
- What is the configuration for fuel injection: a liquid jet, spray? For spray injection, is there consideration of the presence of droplets, and if not why not?
- Why is the fuel dodecane for the fuel injection studies while it was noted to be iso-octane for the RCM work?
- What was the computational time for the multimode combustion modeling effort under Task 1?
- The IDT data seemed scattered in the IDT versus temperature plot. Please comment.
- The effort on plasma chemistry is interesting. The assistance of an OEM here could help to facilitate potential transitioning of the computational modeling of high energy ignition to product design.
- For the ML framework, what is the relevance to considering a 0D (homogeneous) reaction configuration? Similarly for channel flow configuration for turbulent wall modeling.
- It would be helpful to show the big picture of how the wall modeling, plasma ignition, and multimode modeling work can all be incorporated into an engine solver, say Converge for example.
- Task 4 notes that an E30 surrogate was used. It was not clear what this consisted of, for example the components, fractional amounts and how they were determined. For the TPRF-E what were the fractional amounts of the constituents, and how was its kinetic mechanism developed?
- Provide more details of the wall heat transfer model.

Reviewer 4

The reviewer remarked accomplishments are satisfactory, and could be made stronger by clearly showing the change made, and the attendant quantitative benefit. Modeling of a ducted fuel injector is an accomplishment, but how does that move the state of the art forward?

Reviewer 5

The reviewer said it was a little disappointing to see that the LES predicted pressure trace is unable to replicate the RCM's pressure trace and is in line with the 0-D non-adiabatic simulation. This shows that the RCM has no turbulence (and hence no turbulence-chemistry interaction) and the inadequacies are in the chemistry. Before digging into the soot model issues, the reviewer would recommend getting some experimental data on equivalence ratios, polycyclic aromatic hydrocarbon (PAH) concentrations, acetylene concentrations and compare those with numerical simulations to understand whether the chemistry is being mimicked correctly by the model.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said very good coordination across the team with the limited budget in place.

Reviewer 2

The reviewer said great collaboration with partners.

Reviewer 3

Each of the three research groups seems to have a clear assignment on the tasks. While there is no overlap, there is also little significant collaboration among the three groups, except that UCONN worked on a reduced mechanism and ANL applied it in Task 4. There is no industry involvement observed or pathway provided to eventually transfer the capabilities being developed into the hands of industry. The reviewer said the tasks of each group seem to be well defined and distinctly different. The chance for the collaboration among the three groups seems low. The reviewer remarked that collaboration with industry needs to be encouraged, for example, non-equilibrium wall model could be used for industry to improve prediction of wall-heat transfer in engine simulations.

Reviewer 4

The reviewer said the project would benefit from having an OEM on the team. This could facilitate transfer of the results of the project to the prototype design space.

Reviewer 5

The reviewer remarked the project would benefit by having an industry partner.

*Question 4: **Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?***

Reviewer 1

The reviewer remarked proposed future research aligns with the objectives of the original project proposal. The project has a clear next-step plan for tasks.

Reviewer 2

The reviewer said proposed research is acceptable.

Reviewer 3

The reviewer commented proposed future work is satisfactory.

Reviewer 4

The reviewer said proposed future research looks good, no comments.

Reviewer 5

The reviewer said that future work will include validating PEC with RCM data, extending model reduction methods to plasma kinetics, analyzing ignition model against DNS, and data from a spark ignition calorimeter. Some discussion of the latter should be provided, specifically conditions of operation and relevance. The reviewer remarked please be more specific on what is meant by ‘algorithmic development’ for multimode engine simulations in the future work.

*Question 5: **Relevance: Does the project support the overall VTO subprogram objectives?***

Reviewer 1

The reviewer said certainly, these technical barriers will help the future off-road applications as well.

Reviewer 2

The reviewer remarked multi-mode combustion might have limited relevance going forward, but the fundamental learnings will still apply.

Reviewer 3

The reviewer said this project supports Co-Optima program and hence is a steward of DOE funds.

Reviewer 4

The reviewer remarked the PIs note the need for high accuracy modeling tools for implementing new strategies for control and optimizing multimode combustion. The submodels being developed are considered to improve simulations of various elements such as wall heat transfer, ignition, and combustion mode transition. Also, the numerical tools being developed have potential to lead to more efficient simulations.

Reviewer 5

The reviewer remarked fundamentally, the project supports the VTO subprogram objectives. However, industry involvement or a plan to transfer the technology being developed into industry hands would significantly enhance the project's ability to fully fulfill the VTO subprogram objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer remarked the budget may seem a bit low to the reviewer. It will be hard to manage all these activities with the budget.

Reviewer 2

The reviewer thinks DOE can invest further in this project for additional experimental results for a thorough model validation. The reviewer feels the funding of $160,000 is definitely less for the value achieved considering it is nearly a 3.5 year project.

Reviewer 3

The reviewer said there is no indication that the research groups have encountered any issues on resources, etc., and the proposed future research seems manageable to the research groups.

Reviewer 4

The reviewer said resources are adequate, and should not be increased.

Reviewer 5

The resources seem adequate, though without more details (e.g., overhead rate, scientist and technician salaries, equipment costs, etc.) beyond the bottom-line costs for the project provided in the presentation, it is not possible to adequately score this category. An ultimate judgement of costs come from a cost/benefit analysis based on DOE's investment relative to the perceived value of what the PIs are pursuing.

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

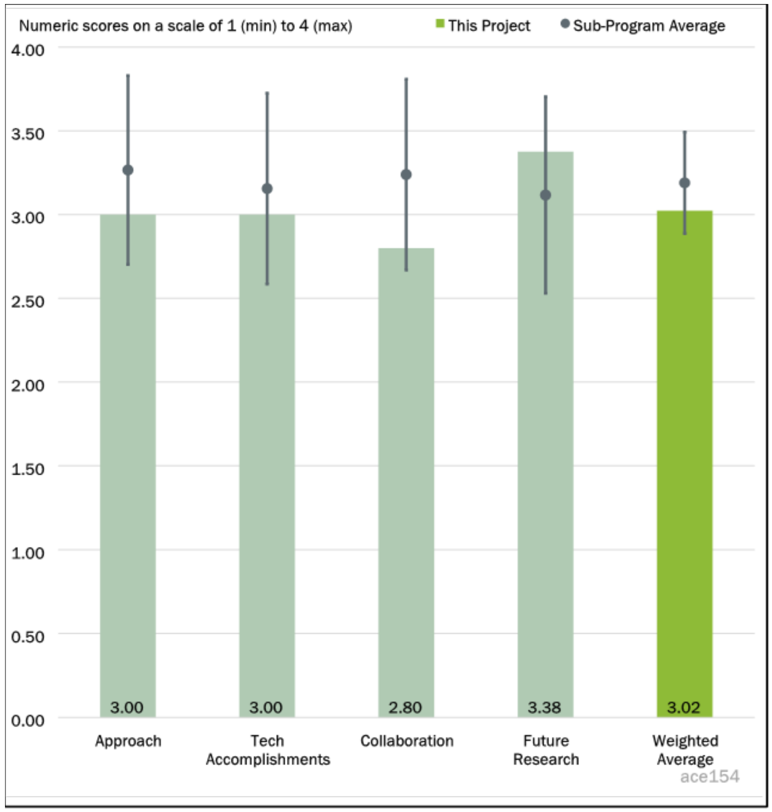

Figure 1-11 - Presentation Number: ace154 Presentation Title: Heavy-Duty Hybrid Diesel Engine with Front-End Accessory Drive-Integrated Energy Storage Principal Investigator: Chad Koci, Caterpillar

Presenter

Chad Koci, Caterpillar

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer remarked the project is nearing completion, this project included sound approaches to increased efficiency in off-road duties. The adaptation of the engine to low-carbon fuels was probably not in scope. The technical approach has been carried out with considerable success.

Reviewer 2

The reviewer remarked the final hybrid system demonstration and characterization has yet to be done. The techno-economic analysis will be very useful also—hopefully this can be made public (or perhaps a public version can be made available) as the additional hybrid component additions will need to be offset with operational efficiency.

Reviewer 3

The reviewer remarked the project is almost complete. The industrial share was larger than DOE share and the reviewer thinks this is captured by the information presented at the review.

Reviewer 4

The reviewer said the work presented is excellent. A comprehensive analysis and assessment of an extremely complicated hybrid system—downsized concept engine with thermal barrier coatings, a Super Turbo with

Turbo-compounding, and high-speed flywheel—has been carried out. The researchers are in their final stages of equipment testing and it appears to be going well. We will find out at the end of the no cost extension. The reviewer said the work shows the level of complexity associated with applying hybrid concepts to unique off-road applications and gives a breakdown of the improvement potential of the different aspect of their approach. The techno-economic analysis will be interesting, and informative.

Reviewer 5

The reviewer said the project is well designed and the timeline is reasonably planned. However, the project was not completed on time (95% complete with 3-month no cost extension granted) and some of the architecture selection decisions could have been better. The architecture selected for this project seems to be an overkill and the system is unnecessarily complex with most of the efficiency improvement contributions coming from downsizing the baseline engine to the smaller concept engine.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer said this project evaluated some very interesting hybrid configurations. While the final demonstration will be important, communicating these results to the broader engine community will also be very beneficial. Additional technical papers are encouraged that explain in detail the various approaches. It appears that a 'best' approach will be a strong function of the operating cycle—publishing these results is important.

Reviewer 2

The reviewer remarked the architecture selected for this project will make this a very costly product and most likely not to be commercially viable. The project team should evaluate whether some of the technologies investigated in this project such as the turbo-compounding, flywheel, thermal barrier coatings, and even the start/stop implementation should be replaced with more cost-effective alternatives. The reviewer remarked most of these have very little efficiency improvement contributions and may even have offsetting effects. The project team should also evaluate the control systems complexity.

Reviewer 3

The reviewer noted that it is an incredibly complicated system, and the research team has done a great job of overcoming the multitude of challenges in putting the system together.

Reviewer 4

The reviewer said progress has been systematic and the final configuration has been refined. Project targets appear to be achievable in the last months of the project. It would have been useful had the efficiency gains in the base downsized engine been reviewed in more detail. Perhaps the information is in the SAE paper cited.

Reviewer 5

The reviewer said it was difficult to extract the actual technical accomplishment when so much is linked to actual CAT products. The reviewer was not very clear what the work on other components than the engine downsize achieved for future research directions. The reviewer suggested that the final report should say more about the directions for flywheel and superturbo design, for various applications that may require individual optimization versus a "universal" approach.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said there was broad-based collaboration and coordination between an OEM, critical component suppliers, and a university within the project team.

Reviewer 2

The reviewer said the project is winding down. From the presentation it was not clear how the different groups created a synergy of effort.

Reviewer 3

The reviewer said the project appears to be largely an effort by Caterpillar, which is sensible for the work scope. Collaboration partnering not a strong part of the effort.

Reviewer 4

The reviewer remarked it seems like there is good collaboration between Caterpillar and the suppliers; however, it is not clear what University of Texas at Austin is contributing.

Reviewer 5

The reviewer was not very clear what the academic partner was doing in this project.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said the various hybrid approaches in this study are interesting and useful. Detailed sharing of the results will be an important conclusion to this work.

Reviewer 2

The reviewer noted the project ended in June 2022.

Reviewer 3

The reviewer remarked the work is proceeding well and with the no-cost extension it appears the final results will demonstrate the technical targets set out at the beginning of the program.

Reviewer 4

The reviewer said there is quite a bit of work to be completed and documented at this late stage of the project. The key deliverables are documented/recognized and will be valuable when achieved.

Reviewer 5

The reviewer said the future work listed are the remaining tasks required for project closure which is already at the last year and the project has been granted a 3-month no-cost extension. The reviewer said future work will most likely achieve its targets but the proposed solution will be cost prohibitive making this not likely to be commercially viable.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said the project is relevant and will support the overall VTO objectives if cost challenges with the proposed architecture solution can be addressed for commercialization. However, during the project review the OEM could not commit on any plans to commercialize this solution, which is to be expected.

Reviewer 2

As with many others, the reviewer believes the future in mobility will be more specialized technology for specific applications. The challenge will be additional cost, but there seems to be much opportunity to hybridize wisely for unique applications. Additional cost will be offset with the increased efficiency.

Reviewer 3

The reviewer remarked increasing engine efficiency for heavy-duty applications is an important part of VTO mission.

Reviewer 4

The reviewer said the program will show the complexity and potential benefit of hybridizing the unique duty cycles of off-road vehicles.

Reviewer 5

The reviewer commented emissions of GHG and other pollutants, and fuel consumption, is significant in the off-highway sector. Efficiency is a great lever to reduce CO_2 and requires no major changes in infrastructure. Unfortunately, low-carbon fuels were apparently not in the work scope.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer remarked it appears that the project will be successfully completed with the resources supplied.

Reviewer 2

The reviewer said resources appear to have been good.

Reviewer 3

The reviewer said resources for this project were sufficient to achieve the stated milestones in a timely fashion. Even though the project was not completed by the end date and an extension has been granted, the project will be completed within the allocated budget.

Reviewer 4

The reviewer said resources are at least adequate. The cost share by Caterpillar is pretty significant.

Reviewer 5

The reviewer noted that industrial partner funding share was more than 50%. It is difficult to comment on resources when it is so expensive to develop and test components such as those in this project.

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

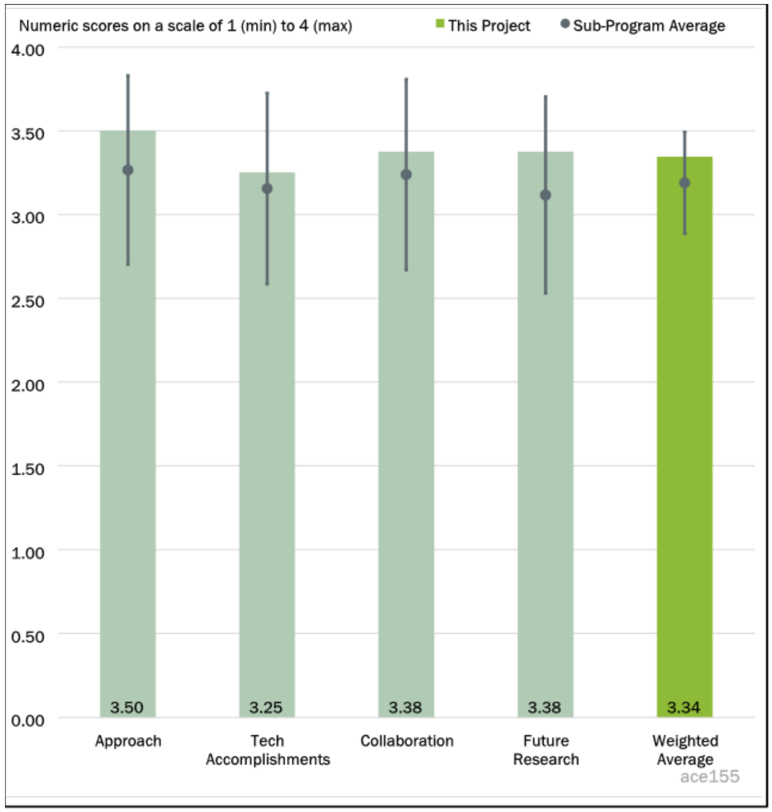

Figure 1-12 - Presentation Number: ace155 Presentation Title: Low-Mass and High-Efficiency Engine for Medium-Duty Truck Applications Principal Investigator: Qigui Wang, General Motors

Presenter

Qigui Wang, General Motors

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

75% of reviewers felt that the project was relevant to current DOE objectives, 25% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer noted the combined use of advanced materials, manufacturing, and combustion strategies expands engine efficiency, but also enables a lighter weight engine with increased performance and fuel economy. The project will help bridge the technology gap between light- and medium-duty engines. The approach implemented in this project could be applied to other engine systems to shorten development time and cost while reducing energy usage and CO_2 emissions.

Reviewer 2

The reviewer said the approach is solid. Largely relies on moderate-risk technologies that should be able to meet program targets with sufficient development. Some of the technologies such as additive manufactured pistons are quite interesting in a technical sense but do not hold much promise for near- or mid-term production introduction, so they are not as relevant to the technology transfer aspect of VTO goals as would be liked.

Reviewer 3

The reviewer said though not extensively covered in the presentation, the backup slide describing Phase II was very well laid out. Nice to see the connections identified to other VTO projects.

Reviewer 4

The reviewer said given the focus on fuel efficiency and weight, the team seems to have a good plan to deliver. Both metrics seem aggressive, but given the large funding, the reviewer expected more concepts to deliver to be investigated.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer is a little concerned about the actual demonstrated fuel economy gain relative to the predicted gain. The PI's organization has a very long history of successful combustion and engine system development and most of the improvements that were pursued were not exotic. The reviewer would have expected much better efficiency results by this point in the program and has some concerns about the pathway to a successful program completion.

Reviewer 2

The reviewer is not too critical of the delays caused by COVID and getting the steps out of sync. However, the measured fuel economy improvement compared to the model predictions were disappointing (Slide 8). The team does appear to be taking actions to rectify this performance shortfall and will still meet the project goals.

Reviewer 3

The reviewer remarked while the technical accomplishments of this project have not entirely met all of the goals, the team has a identified why and has a solid plan for meeting the goals.

Reviewer 4

The reviewer remarked given 55% of the project is complete, progress to deliver all of the goals seems somewhat at risk. Project leaders did not answer some of the reviewer questions around actions to deliver on the cost goals.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said the assembled team has a diverse set of backgrounds (academia, national labs and industry) that cover the needs of the project.

Reviewer 2

The reviewer remarked overall, this project has a good, collaborative team. Perhaps the disappointing combustion predictions could have been improved by leveraging some of the advanced, high fidelity modeling tools being developed by the National Labs. Collaboration on the materials aspects of this project look great.

Reviewer 3

The reviewer remarked there is clear activity at all of the team organizations, and that activity is culminating in hardware to work with at the prime organization. It is not clear if there is strong collaboration or if the activity is more supplier-purchaser activity.

Reviewer 4

The reviewer was surprised not to see more collaboration with customers, or even dealers or other forms of voice of the customer. Fuel efficiency, weight, and of course cost are three of the highest level demands by customers and the lack of engagement by these parties is concerning. The reviewer is generally critical of most DOE VTO projects in this area, but it stood out here on this one.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said the team has identified appropriate corrective steps to get back on target for fuel economy improvement for the build in task 3 this year.

Reviewer 2

The reviewer remarked the project team understands the goals of their project and how to meet them.

Reviewer 3

The reviewer remarked the proposed work to build the engine and demonstrate the weight reduction seems well in hand and just requires time to execute. Not much information was provided to give any solid guidance on how the engine efficiency gain will be achieved. Some new combustion designs were discussed but predictions of their benefit relative to what was predicted for the first round of hardware was not given.

Reviewer 4

Again, concerned about meeting all goals including cost.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said yes, fuel efficiency improvement fulfills the objective of the Advanced Engine and Fuel Technologies subprogram, and the weight reduction is leveraging the materials subprogram.

Reviewer 2

The reviewer remarked the project supports high efficiency and lower emissions including CO_2.

Reviewer 3

The reviewer must say, spending this much money on a diesel engine program when battery electric powertrains are evolving to be a clear solution for much of this market seems misplaced. The reviewer realizes the award was years ago as BEVs have matured.

Reviewer 4

The reviewer said it is very unfortunate in these programs that VTO selects such outdated baselines for the participants to measure against. The engine that General Motors (GM) sold for this application in 2015 was a completely different engine than that which is offered today. The new engine was developed to satisfy U.S. Environmental Protection Agency (EPA) Phase 2 GHG rules and so already offers a significant improvement in efficiency relative to the baseline engine for the program. This then means that many of the technologies developed for this program are not as aggressive as they could be. If VTO funds are going to be used to support advanced development at OEM's, it seems that the goals should be much bigger or the baselines should be much more current.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said the program budget seems fully adequate for the scope.

Reviewer 2

The reviewer remarked resources seem to be appropriate to meet the project goals.

Reviewer 3

The reviewer said the resources are sufficient.

Reviewer 4

The reviewer commented that resources seem sufficient.

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

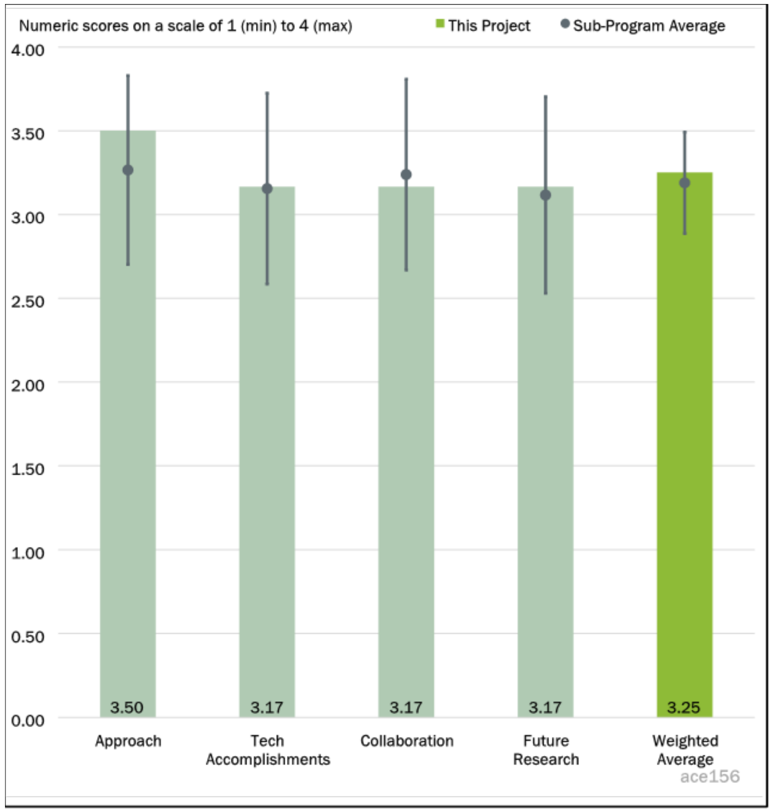

Figure 1-13 - Presentation Number: ace156 Presentation Title: Next-Generation, High-Efficiency Boosted Engine Development Principal Investigator: Michael Shelby, Ford

Presenter

Michael Shelby, Ford

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said the approach is largely based on a change in the engine configuration from V- to inline and adopting advanced but largely understood technologies. The probability of success for the project to meet the goals is high.

Reviewer 2

The reviewer commented that the approach extensively leverages analytical tools in the design and evaluation of concepts such as combustion system concepts for dilution tolerance, efficiency, and knock resistance. The use of simulation, single cylinder engines, and multi-cylinder engines to meet fuel consumption targets is solid.

Reviewer 3

The reviewer commented that approaches taken include all key elements to achieve the program goals. However, it seems to overestimate the impacts on the weight reduction due to the conflicting goal on the fuel consumption reduction in the early planning. Clearly, many technologies taken would increase the weight.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer remarked progress has been on track and generated promising results for both efficiency improvement and mass reduction. There is some delay in the project at present but the PI has a plan to hopefully get the project back on schedule during the current budget period. Current progress looks like it is on track to achieve the program goals.

Reviewer 2

The reviewer said that while there have been some delays, the accomplishments of the team have been outstanding.

Reviewer 3

The reviewer said the project looks good on the achievement of the fuel consumption reduction. However, it underestimates the technical challenging to reduce the weight at the same time.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer commented collaboration between the team members is outstanding and contributes to the success of the project.

Reviewer 2

The reviewer remarked the team members have task descriptions which appear to be progressing well. From the presentation it is unclear how much activity is coordinated between the members and how much is simply done independently and supplied to the PI as needed.

Reviewer 3

The reviewer said that while two key partners—FEV and ORNL—play a crucial role in helping to achieve the program goals, it is still not clear whether they are able to overcome the conflicting goals between fuel economy and weight reduction, thus helping the program to achieve the goals.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer stated the team understands the remaining challenges have added technologies to evaluate to meet the goals.

Reviewer 2

The reviewer said the efficiency improvement appears to be well in hand and to not require a massive ongoing effort. But the PI has identified a gap in the weight reduction that must be addressed. The proposed work to close that gap is very minimally described so it is difficult to evaluate if the plans are suitable or not.

Reviewer 3

The reviewer said the proposed future research provides the detailed steps on what they need to do next by identifying the main challenges. However, it is not clear how these steps can help the program to achieve the program goals on both fuel consumption reduction and weight reduction.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said the project is relevant to the goal of meeting higher fuel economy with lower emissions.

Reviewer 2

The reviewer affirmed it does support overall VTO objectives.

Reviewer 3

The reviewer's comments on this project are primarily directed at VTO and not the project team. They are the same as this reviewer had provided for the companion project awarded under the same FOA and topic area. The goals of the project as defined by VTO are not very aggressive and do not even push technology fast enough to satisfy EPA GHG and fuel economy targets, so the project is relevant to the published VTO goals but is not relevant to the actual needs of industry and consumers. This is not the fault of the project team as they are simply working to what VTO defined.

Question 6: ***Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?***

Reviewer 1

The reviewer said the budget seems good for achieving what is required.

Reviewer 2

The reviewer said resources are sufficient to meet the project goals.

Reviewer 3

The reviewer remarked it would be very challenging to meet the weight reduction goals under the current budget. Because of that, Ford may not have the enough funding to complete the program goals.

Presentation Number: ace158
Presentation Title: Slashing Platinum Group Metal (PGM) in Catalytic Converters: An Atoms-to-Autos Approach
Principal Investigator: Wei Li, General Motors

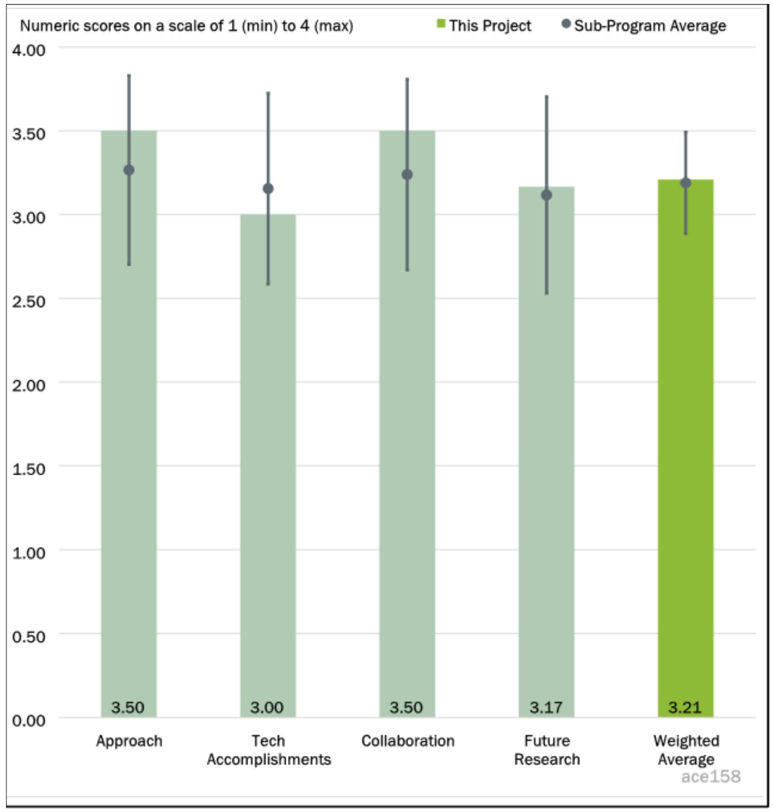

Figure 1-14 - Presentation Number: ace158 Presentation Title: Slashing Platinum Group Metal (PGM) in Catalytic Converters: An Atoms-to-Autos Approach Principal Investigator: Wei Li, General Motors

Presenter

Wei Li, General Motors

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said the overall approach of using engineered supports, optimized deposition strategies and formulations, aggressive aging conditions, and scalable processes should identify promising pathways to three-way catalysts (TWCs) with lower PGM loadings. It would have been nice if the team could share a bit more about their fundamental understandings of what worked and what did not or to share a broader set of data that led to their current best formulations.

Reviewer 2

The reviewer said the approach to develop a new catalyst formulation method (Two Step IWI) for both palladium (Pd) and rhodium (Rh) is very appropriate to problem, if it works, as it appears to.

Reviewer 3

The reviewer remarked the project is well conceived with much potential for success. The project is well organized and looks to be on track although the actual “results” from the research are limited.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer said the targets appear to have been achieved, but more data presentation of catalyst characterization (TEM, more reactor data) to support claims would have been appreciated. Seeing the kinetic data on the catalyst would provide understanding for the controls of the emission control software.

Reviewer 2

The reviewer remarked that the summarized results show impressive performance and excellent progress toward reduced PGM loadings, although the limited data and information shared in the presentation make it a bit difficult to fully evaluate the project progress.

Reviewer 3

The reviewer noted that while milestones for budget period 1 appear to have been met, the results provided in the presentation are not extensive. Most of the presentation describes the concept, which includes results from the existing literature.

The reviewer said the word “optimal” is used in one of the milestones. Optimal relative to what? Because this is a “completed” milestone, stronger evidence of why the catalysts prepared are optimal is needed.

The reviewer noted that the catalysts have been prepared with some characterization and testing, including diffuse reflectance infrared Fourier transform microscopy (DRIFTS) and light-off. The DRIFTS spectra shows a peak at 2080 1/cm that is purportedly CO bound to single Pd atom. It would be worthwhile to corroborate this assignment by providing the relevant literature, DFT calculations, etc.

The reviewer noted that the T50 plots provided do not show the actual temperatures. Why? Are the findings proprietary? The reviewer said no exposed metal area (dispersion) measurements or TEM images are provided, which would provide essential information about what the synthesis has produced. The research would benefit from kinetics measurements for simpler feeds, such as CO and propylene. This would enable the team to compare their catalysts to the extensive literature. Hopefully such missing elements are being investigated during budget period 2.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said a really excellent project team to fully explore, create, and characterize the new catalysts. Not too much seen from some of the groups.

Reviewer 2

The reviewer remarked the project team has a nice balance of roles and responsibilities. However, the project would benefit, as stated above, from kinetics and kinetic modeling and more extensive catalyst characterization including metal dispersion and electron microscopy.

Reviewer 3

The reviewer said the team covers all the basis, with an OEM leading the project and developing formulation strategies, a catalyst supplier to support baseline catalysts and scale-up, universities for novel catalyst development and fundamental investigations, and a national lab for detailed characterization. It would have been nice to see a few more details about which partner generated particular results or work components throughout the presentation.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said future work is a logical progression of the prior efforts and will eventually show whether the reduced PGM formulations can achieve desired performance under realistic operating conditions.

Reviewer 2

The reviewer said proposed future research goals are very appropriate. Full participation of the team will be needed with more supportive data.

Reviewer 3

The reviewer said that in light of earlier comments, the future work is vague, and the reviewer would have liked to have seen evidence of missing elements from budget period 1 at least queued up for budget period 2. The reviewer said the project needs some indication of plans to disseminate the results to the open literature.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said certainly a relevant project for reducing the cost of aftertreatment catalysts.

Reviewer 2

The reviewer remarked achieving the goals of the project will lead to excellent energy efficiency of the ICE-aftertreatment system.

Reviewer 3

The reviewer was not clear how this project addresses the DOE VTO mission of decarbonizing the transportation sector.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said the skills and resources held by the project team are excellent and, with focus, are well matched to the goals of the project.

Reviewer 2

The reviewer stated the project plan seems well designed to achieve the project goals within the available resources.

Reviewer 3

The reviewer commented the budget appears more than adequate to meet project objectives with nearly 50% cost share provided.

Presentation Number: ace159
Presentation Title: Reduced Cost and Complexity for Off Highway Aftertreatment
Principal Investigator: Ken Rappe, Pacific Northwest National Laboratory

Presenter

Ken Rappe, PNNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

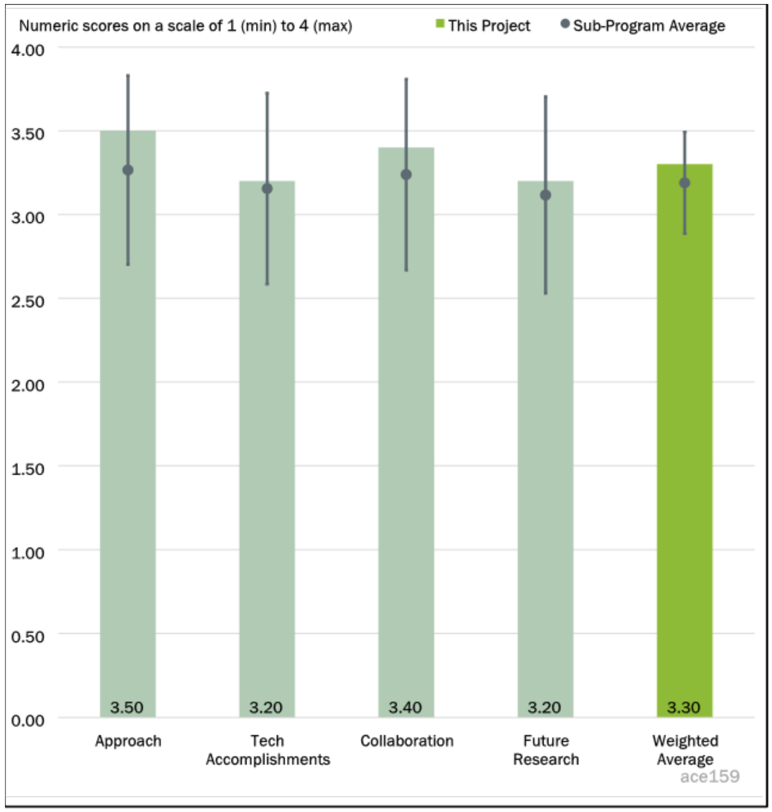

Figure 1-15 - Presentation Number: ace159 Presentation Title: Reduced Cost and Complexity for Off Highway Aftertreatment Principal Investigator: Ken Rappe, Pacific Northwest National Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer commented the off-highway industry typically takes on-highway aftertreatment and applies it to off-highway. This project's goal is to optimize the system (reduce the size, improve the efficiency, and reduce the PGM). This will be accomplished by improving the Michigan Technological University (MTU) combined diesel oxidation catalyst and diesel particulate filter (DOCF) model by collecting in situ diesel oxidation catalyst (DOC) data with the Spaci-MS, determining the porosity and permeability using high resolution X-ray computerized tomography (CT) data, and verifying the model with laboratory engine results. The reviewer believed the project is well designed, is on schedule, and should be able to meet the stated goals.

Reviewer 2

The reviewer said using Spaci-MS to get detailed concentration and temperature profiles should provide unparalleled insight. The team is making reasonable progress in showing the capability of the SpaciMS method. In addition, modeling is applied to exploit the information provided by the data. The intent of the project is to advance the DOCF to simplify off-road DOC + diesel particulate filter (DPF) combination.

Reviewer 3

The reviewer said the approach to developing and modeling a DOCF device seems well conceived, especially with the inclusion of Spaci-MS information to test the model against as the gases flow down the device.

Reviewer 4

The reviewer stated this is a straightforward project in terms of the focus on a technology. It is of course not straightforward in terms of the development of said technology. The team has addressed the planned activities and barriers. It looks to be on path and target. The reviewer said the knowledge being gained is important to the field and appears that it will lead to a tangible solution.

Reviewer 5

The reviewer posted the following questions. In what way is the DOCF different from a continuously regenerating trap (CRT) system developed by Johnson Matthey, or even a simple catalyzed DPF that is commonly observed in all diesel engines? Is gravimetric weighing of the filter performed for soot loading tests on the engine? Why is there an increase in CO emissions along the axial direction? From the previous reviewer's comments, it appears that not enough testing was dedicated to understanding the soot management issue. The interaction of soot loading to nitrogen dioxide (NO_2) production is yet to be assessed.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer said the MTU DOCF model has been updated to include 13 additional parameters from the initial 6 that were in the previous model. PNNL has developed the Spaci-MS and has collected data to verify the reaction kinetics. Finally, Kymanetics has performed the high-resolution X-ray CT scans to assist in determining the key parameter for the MTU model. The reviewer said it appears that everything is coming together. As stated earlier, the project is on schedule and the reviewer does not see any roadblocks that will slow down the team.

Reviewer 2

The reviewer said the team has made good progress in understanding their system and in designing a new system to integrate the devices and even improve performance versus baseline.

Reviewer 3

The reviewer said Spaci-MS appears to be working well in the data seen and will be very important in the model evaluation. The baseline model and characterization of the system have been completed. We await a more detailed comparison in the coming year.

Reviewer 4

The reviewer remarked while progress has been made with both experiments and modeling, what is not clear is how progress will be made towards advancing the DOCF. Critical to this reviewer is demonstrating the Spaci-MS method with the baseline conventional DOC+DPF so that meaningful conclusions can be drawn in the integrated DOCF. In other words, what testing shows that the integrated DOCF can treat the same gas as the sequential unit, and beyond that, how to show that the PGM loading can be decreased at the same time? Answers to these questions are not evident in the presentation. The reviewer remarked the team needs to clear think this through and provide a detailed plan.

Reviewer 5

The reviewer said technical accomplishments from the engine testing have not been clearly presented. Significant groundwork has been accomplished in model development. It is not clear why some parts of the selective catalytic reduction on filter (SCRF) model were reused, and the reviewer asked would not models of a catalyzed DPF be more suited than an SCRF? The reviewer said it would be interesting for the team to consider any CRT models if they are available for benchmarking purposes

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said there is clear collaboration across the team, in not just attending but actually participating and developing the technology.

Reviewer 2

The reviewer remarked collaborators are excellent for this project, especially for what the interaction between John Deere, PNNL, and MTU potentially offers.

Reviewer 3

The reviewer remarked the team of John Deere, PNNL, MTU, Kymanetics, and Carus is an outstanding collaboration that covers all aspects of the project. The project's current collaboration is sufficient.

Reviewer 4

The reviewer detailed the project team consists of PNNL, John Deere, MTU, Kymanetics, and Carus. PNNL, MTU, Kymanetics and John Deere have significantly contributed to the project and their contributions were pointed out in the presentation. Carus should become more involved in the future when they start to evaluate the mixed metal oxides in year 3. The reviewer said overall, good collaboration from all parties.

Reviewer 5

The reviewer said the project team has appropriate collaboration across the organizations involved.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said that as most projects, the first 2 years are kicking off the project and setting up for big advances in the later years. The DOCF model has been improved and needs to be verified with engine data. Once that is verified, the model will be able to assist in improving the catalyst and the intent is that the mixed medal oxide will allow thrifting of the PGM. The laid-out tasks are sound and should lead to a successful project.

Reviewer 2

The reviewer said the choice of Future Research goals is well designed and focuses on development of the model for temperature and emissions from the DOCF device.

Reviewer 3

The reviewer said the future plan appears quite reasonable and appropriate, and the reviewer is unsure what 3rd gen means (versus 2nd gen etc.), but this appears to be targeted at continuous improvement. It would be good to also figure out if the results from the one system are extrapolatable to enough to be generic.

Reviewer 4

The reviewer remarked the project is titled Reduced Cost and Complexity Aftertreatment system, however, the project fails to explain where the targeted cost reduction is likely to be observed. The merger of a DOC and DPF is a reduced complexity system, however, is the cost reduction only from a material aspect of the total operating cost of the system (DOCF and SCR)? If soot management is not addressed, then the cost associated with the regeneration fuel penalty could be higher than a convention catalyzed DPF. The reviewer said future work is scheduled to address the testing of the validity of the model, soot management, and NO_2 production. This is a critical requirement that needs to be addressed.

Reviewer 5

The reviewer said that plans to close gaps, especially in demonstrating PGM and cost reduction versus incumbent technology, are needed.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer remarked clear support of VTO objectives.

Reviewer 2

The reviewer said VTO has been switching the research focus to off-road and to ensure off-road vehicles will meet future emission regulations at a reasonable cost. This project will accomplish that and the smaller aftertreatment size will have lower engine backpressure, which will lead to better fuel economy.

Reviewer 3

The reviewer remarked the project addresses emissions from engines and is integrating devices to achieve more cost-effective systems.

Reviewer 4

The reviewer commented the relevance of the project to its off-road focus is well covered with John Deere as a partner. The experience of many of the specific collaborators gives confidence that the design and carrying out of the project should be well handled.

Reviewer 5

The reviewer said the project is relevant in reducing the fuel use penalty associated with modern aftertreatment systems and reducing the use of PGM.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said resources resident at PNNL, John Deere, and MTU are quite sufficient for their parts of the project.

Reviewer 2

The reviewer commented resources appear adequate.

Reviewer 3

The reviewer said resources appear to be sufficient. The largest effort will be the engine testing at MTU and with their ability to “cart” the engine they can save test cell time on installation costs. The modeling effort takes time, but that time is well budgeted.

Reviewer 4

The reviewer cannot tell in terms of resources moving forward, as they are not listed. The reviewer will note, however, that although not part of the project, there seems to be overlap in technologies being used between

NLs. Was a new SPACI necessary (and the funds for it and resources spent) versus one to use at a different NL?

Reviewer 5

The project has sufficient resources to achieve its goals of the project. The resources of the engine testing part from MTU are unclear. Does the project have resources such as Fourier-transform infrared (FTIR) spectroscopy for pre-and post- catalyst emissions measurement? Is the PM mass measurement (instantaneous soot measurement) pre- and post DOCF)

Presentation Number: ace160
Presentation Title: Optimization and Evaluation of Energy Savings for Connected and Autonomous Off-Road Vehicles
Principal Investigator: Zongxuan Sun, University of Minnesota

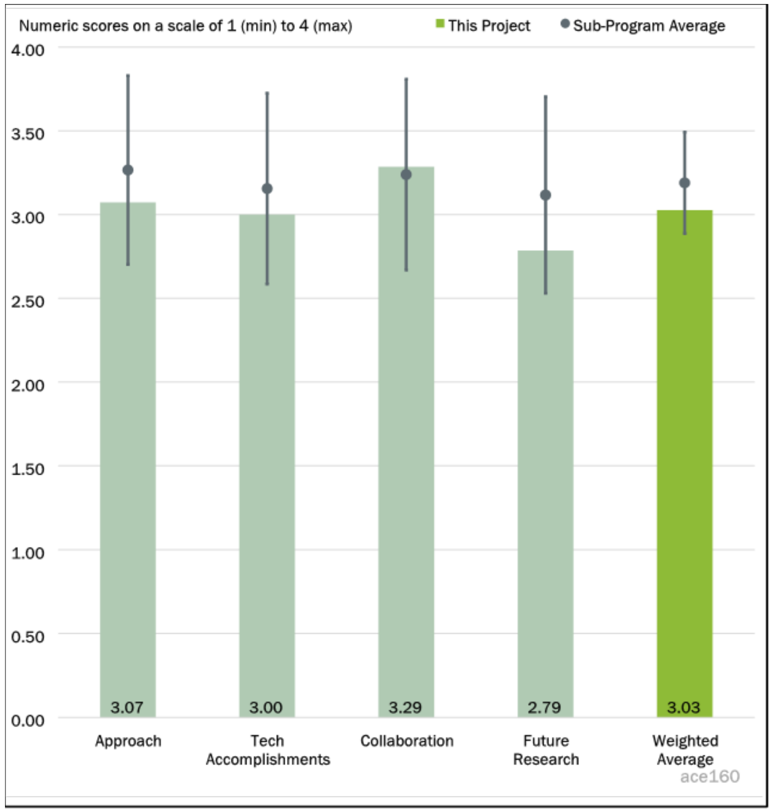

Figure 1-16 - Presentation Number: ace160 Presentation Title: Optimization and Evaluation of Energy Savings for Connected and Autonomous Off-Road Vehicles Principal Investigator: Zongxuan Sun, University of Minnesota

Presenter

Zongxuan Sun, University of Minnesota

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said the stated goal of this project is to use connectivity and automation to reduce energy consumption and increase productivity for off-road vehicles. The objective is to develop systematic optimization and control methods for connected and autonomous off-road vehicles. Successful implementation is expected to achieve 20%-40% energy savings and improve machine productivity. The reviewer said a hardware-in-the-loop (HIL) testbed will be constructed to evaluate energy savings potential of the control and optimization strategy. The intent is to use the HIL testbed to evaluate the energy benefits of different levels of automation. This is an excellent approach to improving efficiency of off-road vehicles through automation. Because the wheel loader is filling a truck, the use of automation necessitates inter-vehicle connectivity. This barrier is addressed by Worksite simulation and communication system.

Reviewer 2

The reviewer stated the project is well designed and the timeline is reasonably planned. The project team has done a fantastic job in defining the critical application functions that capture the architecture complexity for solving the system optimization problem.

Reviewer 3

The reviewer remarked the simulation and control optimization of the machine in this study is superficially explored and the conclusions are not break-through but rather expected and heavily focused on the very basic operation of a machine, which is very well known (at least by industry). Time-wise, it is challenging to give a positive comment based on how long it has taken (50% percent of the project time) to create such model and optimization. Additionally, the project title focuses on the connectivity of the machine and automation, but the presenter failed to comment or even demonstrate that any work at all has been done to tackle the real-life challenges of automating and communicating with the machine.

Reviewer 4

The reviewer commented the team is addressing the operator inefficiency barrier through developing an automated workgroup function during the dig cycle to optimize efficiency and bucket fill. The team is also addressing the operator inefficiency in the drive cycle through optimizing the drive path to maximize efficiency while maintaining operator cycle times at a minimum. The presenter indicated how the dynamic interactions between the workgroup and drive functions can lead to efficiency improvements. The reviewer said it would be beneficial to see how the team is optimizing dynamic interactions of the workgroup and drive and the efficiency gains achieved in doing so.

Reviewer 5

The reviewer agree with the technical barriers that the research team has presented. However, the challenges of the variations in the materials (soil and gravel) being acquired and transported (soil or gravel, etc.) and the expertise levels of the operator have not been addressed. It is important to establish robustness to these variations in any optimization scheme.

Reviewer 6

The reviewer questioned the approach. It is still not clear why the engine model is not used and why the project had to spend time and money developing HIL. The engine model could have been created like those of the propulsion and hydraulic circuit that were used in the project. Fuel consumption could be obtained from a good engine model and associated brake-specific fuel consumption (BSFC) maps.

Another question is related to the baseline wheel loader cycle: How is the machine baseline cycle determined. What is machine productivity in the baseline cycle? Is the productivity of the improved cycle verified and what are the values? The reviewer said fuel efficiency should be determined after productivity has been verified. It is also not clear what is the total opportunity for energy savings is (24.3% or...?) Is automation really needed for efficiency improvements; can the operator coaching be done?

Reviewer 7

This reviewer is a strong proponent of HIL systems and has extensive experience designing, building, and using HIL systems. That said, the reviewer questions if making a HIL system is the most efficient and cost-effective way to get to good test results in this situation. Powertrain and fluid power systems are well understood and modeled quite accurately. It would seem that a SIL/MIL setup would allow you to do the optimization more efficiently and those results should be good enough that you could go right to tests on actual hardware to confirm the modeling results. The reviewer can see the HIL system being very effective at testing the software but not sure it should be usedt for the majority of the system testing. At year 2 of 3 and it does not seem like much optimization has been done. That said, the team seems to be getting a lot of work done for the project cost.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer remarked the project team is reporting 50% completion, which is on track with the project plan. Good progress has been made with completed work in the areas of formulating the system optimization problem, developing and validating the vehicle model, and developing the communication system as well as demonstrating preliminary encouraging results on some of the solutions developed with plan on track fully integrated HIL testbed.

Reviewer 2

The reviewer remarked the team has achieved the milestones documented for the project per the timeline presented. The technical accomplishments documented align with the work plan and project objectives.

Reviewer 3

The reviewer said the reported model validation results are very good. It appears that the relevant machine dynamics have been captured. Optimization of the transport phase and digging phase are good first pass approach. The reviewer said that if the cost function is only fuel consumption, then there will be a low likelihood of acceptance in the marketplace, which seeks productivity maximization alongside or probably more than fuel efficiency. Both fuel consumption and productivity need to be in the cost function.

Reviewer 4

The reviewer remarked in this project, wheel loader propulsion and bucket motion have been optimized using model-based optimizations. The team estimated resistance using a model that incorporated fundamental earthmoving equations. The team accomplished model validation using flow, torque, and pressure data provided by the engine manufacturer. The modeling results indicated that automation could decrease fuel consumption by 16% relative to manual operation. 27.9% fuel benefit could be achieved with more aggressive steering. The technical progress is excellent. The reviewer said for the next quarter, the task is to integrate modelling, control, worksite simulation, and communication with the HIL testbed. While the engine and pump are in place, it is going to be a challenge to complete this phase in the allotted time.

Reviewer 5

The reviewer said honestly this was a bit hard to evaluate as the overall plan did not lay out accomplishments in detail in the presentation. A lot of time has been spent on the HIL system. We are close to being done with year 2 of 3 and still working on system models and the HIL system.

Reviewer 6

The reviewer said it is challenging to give a positive comment based on how long it has taken (50% percent of the project time) to just create a virtual model. Moreover, the model does not tackle the most significant challenges within the scope of the project, “Connected and Autonomous” machines.

Reviewer 7

The reviewer noted that good progress is made on the model development. After developing an optimal machine trajectory, the reviewer asked did you check for machine stability and operator comfort (the reviewer referenced a comment about more aggressive steering to gain 27.9% efficiency improvement)? The reviewer asked to please show the aggregate efficiency improvements, and does it exceed the 20% target? The reviewer noted the original project goals were to improve efficiency by using automation and connectivity, and it does not seem that the connectivity plays any role thus far.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

Appears that they have a strong team and are doing good work together.

Reviewer 2

The reviewer said fantastic collaboration and coordination with frequent touchpoints between the universities and OEM partners in the project team as well as well-defined contributions from each of the partners.

Reviewer 3

The reviewer commented the collaboration and coordination summary documented on Slide 17 demonstrate and appropriate level of communication and collaboration for the scope and activities within this project. Both universities and the industry partner are well engaged in the project and have demonstrated they are contributing their share of the work/content to support the success of the project.

Reviewer 4

The reviewer said there is a strong set of collaborators that is meeting in regular intervals, which seem appropriate for the project. The contribution of each collaborator was clearly described.

Reviewer 5

The reviewer said CNH has provided benchmark data from the 521 loader and an engine. The benchmark data great for validating models. The 521 engine is perfect for the HIL dynamometer. Texas A&M provided the FFE model for predicting the bucket forces. Based upon model the correlation between model and benchmark data, the FEE model was effective. If I recall correctly, Texas A&M is providing the worksite simulation. The worksite simulation task seems to be the least developed of all the project elements.

Reviewer 6

The reviewer said it looks like the collaboration between the lead PI and the rest of the team is acceptable, though it is hard to judge the contribution of each. It is great to have an OEM involved for guidance.

Reviewer 7

The reviewer noted that the presenter commented on the commitment of the partners through regular bi-weekly meetings; however, it was not properly explained what the tangible contributions are of the partners in the project.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer remarked the proposed future work consists of constructing the HIL testbed and using it to evaluate the energy benefits of different levels of automation. That is good.

Reviewer 2

The reviewer remarked good things are included in the test plan, though achieving all of that may be optimistic. The reviewer thinks more time will be spent on the testbed than the optimization.

Reviewer 3

The reviewer remarked the purpose of the proposed future research has been clearly defined and based on the preliminary results presented so far, there is a very high likelihood that its targets will be achieved. However, two things were not clear to this reviewer. First, the developed communication system developed has a latency of less than 100 milliseconds with no missing data. Is that the minimum requirement for the selected duty cycle and would the project team need a more capable communication system with even smaller latency, say less than 1000 milliseconds for a highly transient duty cycle. Secondly, how is the project team planning to incorporate or capture critical customer constraints such as least tire wear and ensuring the fullest loaded bucket.

Reviewer 4

The reviewer commented the proposed future research plan on Slide 19 is in line with the overall project plan and well documented. The timeline appears to be reasonable and achievable. I would like to see further clarity around the plan for optimizing the dynamic interaction of the workgroup and drive system. There was significant prior discussion and good work documented around the optimization of each of those functions individually in Slides 9-14, but little to no documentation of the optimization of the interaction of workgroup and drive functions.

Reviewer 5

The reviewer is still questioning the need for using HIL if the model has been validated. Is the approach general enough to transfer this methodology to other machine platforms? Another question is related to automation. How will the team decide what the operator will do versus what the machine automation controller will do (example: digging, driving, using implements etc..)? Is the operator going to interfere with the machine's trajectory and how is that going to impact efficiency, stability, productivity, etc.?

Reviewer 6

The reviewer said the proposed future research with timeline is reasonable and should be achievable. While the approach of separating the digging and transport phase into two separate optimization problems is reasonable, in reality, they are connected during the bucket filling phase of the work cycle. This overlap should be addressed. Similar, the dumping phase has been neglected from optimization and should be addressed. Perhaps is it outside the scope of this project, but field evaluation is important for establishing the performance of this automation and optimization scheme.

Reviewer 7

The reviewer said the proposed future work is to build a test stand to presumably validate some of the model results, which is disappointing as the main real-life challenges are completely disregarded.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer remarked the project is relevant and can lead to some low-hanging fruit for fuel consumption reductions in the near term.

Reviewer 2

The reviewer commented this project is very relevant and does support the overall VTO Advanced Engine and Fuel Technologies objectives because it focuses on optimizing highly connected and autonomous off-road vehicles for energy savings, which is well aligned with the agriculture and construction industry technology trends.

Reviewer 3

The reviewer said this project is focused on efficiency improvements, which aligns with the VTO objectives.

Reviewer 4

The reviewer remarked the project seeks to remove inefficiencies in the wheel loader duty cycle and would result in a direct improvement in productivity (material moved per fuel volume) and aligns very well with the sub-program objectives for system-level efficiency improvement.

Reviewer 5

The reviewer said this project aligns with VTO's goal of accelerating the development of clean, efficient transportation technologies that provide better and cleaner mobility options to lower GHG emissions and reduce petroleum fuel consumption.

Reviewer 6

The reviewer said yes, this project will demonstrate the potential in reducing energy and emissions using optimization and autonomous operation of a specific construction vehicle and operation cycle. The knowledge gained from this work will be extendable to other vehicles and operations.

Reviewer 7

The reviewer said the most relevant argument to run this project would be to explore the challenges for autonomous and connected machines and how to implement the optimization that has been created in the first 50% of the project life. These aspects have not been elaborated on, nor there has been mention that these have been or will be addressed.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said resources are sufficient, but more resources could help ensure all the project goals are achieved.

Reviewer 2

The reviewer said it appears that more resources might be required to integrate the worksite simulation. Otherwise, resource allocation is sufficient.

Reviewer 3

The reviewer said the project is 50% complete at the mid-way point with allocated funding for budget periods to support the proposed future research for the project to achieve the stated milestones in a timely fashion.

Reviewer 4

The reviewer remarked it seems that the project has enough resources to get things done.

Reviewer 5

The reviewer said the level of resource allocated to the project appear to be appropriate for the level of activity and project scope and objectives.

Reviewer 6

The reviewer said the project brings together an excellent team with great experience combined with good DOE and partner resources which should enable the achievement of the stated milestones in a timely fashion.

Reviewer 7

The reviewer said the amount of funding provided for this project relative to the outcome is excessive.

Presentation Number: ace161
Presentation Title: New Approach for Increasing Efficiency of Agricultural Tractors and Implements
Principal Investigator: Andrea Vacca, Purdue University

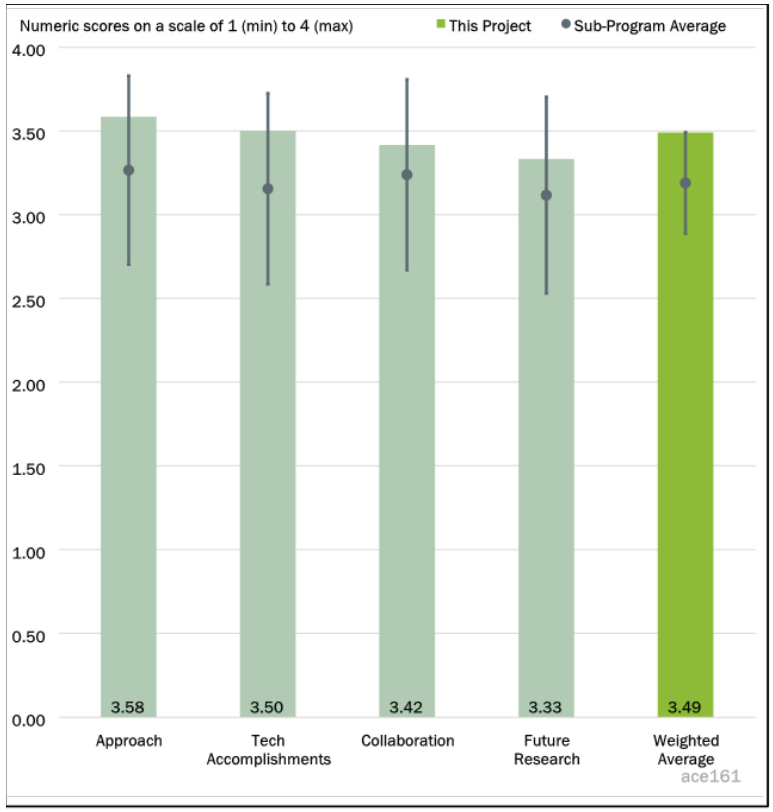

Figure 1-17 - Presentation Number: ace161 Presentation Title: New Approach for Increasing Efficiency of Agricultural Tractors and Implements Principal Investigator: Andrea Vacca, Purdue University

Presenter

Andrea Vacca, Purdue University

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer remarked the objective of this project is to develop and demonstrate a multi pressure rail (MPR) hydraulic control system for a CNH tractor and planter. The goal is to double the energy efficiency of the hydraulic system, thus reducing engine fuel consumption by at least 15%. This is accomplished by benchmarking state-of-the-art planter performance in field tests, modeling and constructing a MPR standalone test rig, and modifying a tractor and planter to incorporate MPR technology. The impact on efficiency will be evaluated in field tests. The reviewer noted that naturally, a lot of modeling and simulation is required to optimize the MPR system. The standalone MPR system is useful for validating the simulations. The overall approach is outstanding. It includes all the requirements to overcome the technical barriers and culminates with a field demonstration of the MRP concept.

Reviewer 2

The reviewer said the proposed concept for meeting the project objectives is fundamentally sound and innovative with well-designed project activities. The results presented at the midway point demonstrate good progress by the project team with reasonable time allocated to the activities outlined in the future research to meet the remaining project milestones.

Reviewer 3

The reviewer said the scope of work to date has been focused on improving efficiency of the hydraulic system and eliminating throttling losses, which is directly in line with the technical barriers documented in the project. The project Is well designed and has a reasonable schedule with well documented milestones.

Reviewer 4

The reviewer noted that low efficiency of conventional load sensing systems like those used in tractors is well known, particularly in mixed load cases like a planter which have both high flow/low pressure loads and high pressure/low flow loads. The MPR system is a solid approach to this problem. Like other reviewers have pointed out in past reviews, the project would be more compelling if it were applied to a larger set of different implement loadings. However, the knowledge gained from the application to this specific tractor implement will have broad application to other use cases. Efficiency gains will need to be evaluated on a case-by-case basis.

Reviewer 5

The reviewer said the hydraulic architecture being proposed is well thought out as is the development plan. The largest concern this reviewer sees will be the increased cost of the system due to the increased complexity. It appears that the team is trying to address this. It is good that the team includes a major hydraulics supplier that is addressing the cost issue from the beginning.

Reviewer 6

The reviewer remarked this project is continuing to make good progress and addressing technical issues. The timeline looks reasonable. There are some technical questions about the approach: By observing Page 5 P-Q charts for the baseline system and improved system, the reviewer is curious if the % improvements are based on the worst-case scenario when the implements are active and consuming 100% flow? Is there a composite cycle that better represents actual machine usage and what would be the expected savings using one of the proposed MPR approaches?

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer remarked fantastic work with good progress being made against the project plan and encouraging results demonstrated so far. With the added complexity, it will be instructive for the project team to evaluate the system sensitivities and whether real-world conditions as well as application duty cycles will erode some of the efficiency increases that have been projected from simulation models and testing in controlled settings used for technology demonstration.

Reviewer 2

The reviewer said the team has made good progress against the proposed test plan.

Reviewer 3

The reviewer said that significant progress has been made on the project as documented on Slides 6-16 of the presentation. One challenge with the multi pressure rail system that can be seen in the graphs presented on Slides 14-15 is the transient actuator speed variation during rail switching. Is this behavior going to be a significant barrier to commercialization and is there a plan minimize the transient actuator speed variation in future work?

Reviewer 4

The reviewer noted that the team has completed baseline field tests on the fully instrumented tractor-planter, and measured the energy efficiency of the standard tractor-planter technology. The team constructed a standalone MPR test rig and collected data. The team validated the simulation model. Simulation of the MPR tractor-planter meet project go/no-go criteria. The reviewer noted that modification of the Tractor-Planter systems is underway. The technical progress is excellent. Can you please explain how efficiency improvement was calculated?

Reviewer 5

The reviewer said researchers have made progress and appear to be meeting the technical milestones listed in the project plan. The team measured baseline efficiency of the tractor and planter combination in field tests, and developed and validated with field test data a system model of the reference tractor and planter system. The MPR system has been modeled and simulated with drive cycles collected from the field experiments showing reduction in power consumption and increases in system efficiency to meet go/no-go 1. The team developed the MPR test rig and used it to determine the MPR architecture. It was not clear what the Gen. 1 and Gen. 2 MPR prototypes were. Expect these are in process and there will be more clearly described in the next AMR.

Reviewer 6

The reviewer said the project obtained good baseline data for the hydraulic system by running an actual machine, which helped with the model validation and identified power losses. Also, the team developed a two-layer controller, and designed and installed an MPR test rig. Controller tested and tuned for best behavior during switching between the rails.

The reviewer said it is not easy to follow all claims about efficiency improvements. Examples: Slide 3: objective to have 15% fluid power functions energy consumption reduction. Slide 4: Simulated MPR delivers over 60% higher efficiency (Is 60% coming from the fluid power functions?). Go/no-go 2 for the MPR delivers 40%. Of what? Slide 12: Increase in system efficiency from 89.95% to 119.32%. Slide 15: Average 45% efficiency gains (2 pump-system). Does this mean that the project will not be able to “double” the efficiency? The reviewer suggests making a table or some other way to summarize and clearly explain different gains. Is the pressure response a concern for the latest configuration and how is that going to affect the performance of the implements?

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer noted that university-owned farms serve as a site for field tests. CNH contributes to the project through personnel that provide expertise in hydraulic components, drives, simulation, and control. CNH also provided the reference vehicles for the technology demonstration and expert operators to assist on the field tests. Bosch Rexroth provides engineering support, and NREL provides analytical support from the Center for Integrated Mobility Sciences. Everything appears to be working together great!

Reviewer 2

The reviewer said this project has broad-based collaboration between university, national lab, OEM, and critical component suppliers with well-defined contributions from all the project partners.

Reviewer 3

The reviewer remarked there is a strong team, and they appear to have close collaboration.

Reviewer 4

The reviewer commented the project collaboration as documented on Slide 17 demonstrates each collaborator is fully participating in the project and achieving the deliverables for their responsibilities. University, industry partners, and a national laboratory are all actively engaged in the project.

Reviewer 5

The reviewer said the communication level is good among all the partners. It seems that the partners are sharing data well and having the machine available at the PI's location is also a big plus for this project. It is still not clear how Purdue and NREL share the responsibility for control strategies and how CNH performs simulation based on the devised and developed control strategies. Is this an efficient way of doing development?

Reviewer 6

The reviewer remarked there is a strong set of collaborators with an excellent set of resources that are available to the project. The contribution of each collaborator was clearly described; however, the frequency of collaborator meeting and interaction should be described and provided to the reviewers.

*Question 4: **Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?***

Reviewer 1

The reviewer said defined future research work is aligned with demonstrating the technology and commercial viability of the proposed system, which is very likely to achieve the project energy efficiency improvement targets based on the encouraging results that have been demonstrated so far in the project.

Reviewer 2

The reviewer said future work documented on Slide 18 demonstrates the work content is focused on the remaining challenges with a clear purpose. The future work is likely to achieve the targets based on the information presented.

Reviewer 3

Upcoming work, which includes extending the system to include more functions, will be key from this reviewer's perspective. It is possible that having to satisfy a larger number of pressure and flow requirements will reduce the overall efficiency gains that can be achieved.

Reviewer 4

The reviewer liked the goal of exploring the opportunity to expand this MPR approach to other tractor functions, and is curious about how "generic" this technology is and how easily it can be replicated to other machine types. In addition, please try to better explain the cost analysis table. Is the second pump included in the cost analysis and the packaging on the machine?

Reviewer 5

The reviewer said proposed future research generally aligns with the timeline and milestones. However, there may be some creep on project scope, which should be managed well to make sure that the key milestones serving the project objectives receive the top priority.

Reviewer 6

The reviewer remarked proposed future work identifies challenges and associated tasks. The way the future work is described does not identify which tasks are sequential and which tasks are concurrent. In the future work table, can the team please explain what is meant by "Simulation of a MPR vehicle connected to a non-MPR one, evaluation of control aspects and energy efficiency?" Also, can the researchers please explain what is meant by "execute field tests according to test plan defined in budget period [BP] 1?" The reviewer thought this was done already. In the milestone chart market analysis is task N and comes in 2023 but it is listed as a 2022 task in future work. The reviewer said based upon previous performance, future research is rated as good, but the way it is reported is confusing.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer noted that this is a reasonably straightforward way to increase efficiency of agriculture equipment that can be extended to other industries

Reviewer 2

The reviewer said the project focus on increasing efficiency of agricultural tractors and implementing it will be beneficial to the off-road industry and supports the overall VTO objectives for the Advanced Engine and Fuel Technologies Program.

Reviewer 3

The reviewer said the project supports VTO's objectives to continue looking into technology development that will improve the efficiency of off-highway machinery.

Reviewer 4

The reviewer commented the project is focused on a system-level efficiency improvement and directly ties to subprogram objectives.

Reviewer 5

The reviewer stated this project aligns with VTO goals by improving the efficiency of commercial agricultural vehicles and reducing fuel consumption, thereby decreasing emissions and operating costs for farms.

Reviewer 6

The reviewer said yes, this project demonstrates the potential in reducing energy and emissions using new hydraulic system architecture that show good potential. The knowledge gained from this work will be extended to other tractors and implemented combinations as well as other off-road vehicles.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said the resources defined on Slide 19 appear to be of an appropriate level and mix of contributors to achieve the remaining project objectives.

Reviewer 2

The reviewer remarked the project plan and budget appear appropriate for this scale of development project

Reviewer 3

The reviewer said the project is on track with a 50% completion rate at the midway point and is operating well within the allocated budget.

Reviewer 4

The reviewer commented it seems that all parties in this project have sufficient resources for the proposed future work. The team is very capable.

Reviewer 5

The reviewer noted that Purdue's Maha Fluid Power Research Center has ample resources. A strong team has been assembled. The budget is steep, but it is justified based upon the project scope, effort, and complexity. Every element of the project is progressing at a good pace. Resources are satisfactorily allocated.

Reviewer 6

The reviewer said the project brings together an excellent team with great experience combined with good DOE and partner resources that should enable achievement of the stated milestones in a timely fashion.

Presentation Number: ace162
Presentation Title: Improved Efficiency of Off-Road Material Handling Equipment through Electrification
Principal Investigator: Jeremy Worm, Michigan Technological University

Presenter

Jeremy Worm, Michigan Technological University

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

83% of reviewers felt that the project was relevant to current DOE objectives, 17% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 17% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

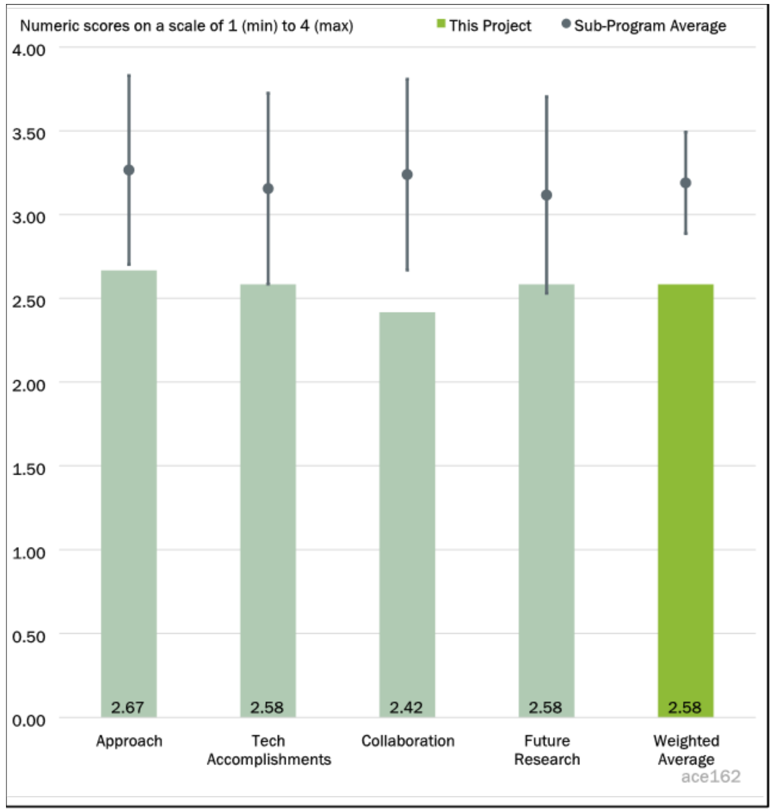

Figure 1-18 - Presentation Number: ace162 Presentation Title: Improved Efficiency of Off-Road Material Handling Equipment through Electrification Principal Investigator: Jeremy Worm, Michigan Technological University

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer stated the approach is well thought out, leverages modeling, real-world drive cycles from an OEM, and appears to have a solid plan for culminating in a hardware demonstration.

Reviewer 2

The reviewer said the project team is taking a systematic approach in addressing the technical barriers that have been identified for this project. Good work is being done in leveraging proven methodologies to develop the standard operating cycles and industry best practices to determine the optimal electrification architecture. The proposed project activities are reasonable and well-designed but the project team might have to be creative in overcoming some of the logistics challenges or critical components procurement delays to keep the project on track.

Reviewer 3

This appears to be a decent workplan, but this reviewer was a little surprised at the clean sheet approach taken here when so much analytical modeling and previous work has been done in this area. It seems the project could have leveraged that more to spend less time on selecting architectures and more time on implementing and optimizing the systems. The reviewer also would have liked to see a bit more discussion on cost. This is a relatively straightforward electrification project and cost is usually the main barrier to commercial acceptance.

Reviewer 4

The reviewer said the three barriers identified by the research are on target, and the researchers are taking a rational approach to address these barriers. The team specifically addressed the second barrier by developing a methodology for producing a standard operating cycle for the material handler and three operations that would be commonly done by the handler. The team only showed vehicle speed for a standard operating cycle, but in reality, regarding the speed of the other handler degrees of freedom must be part of the operating cycle, but those were not shown. The researchers should be more descriptive of what the operating cycle includes. To address the third barrier, many different vehicle architectures were considered relative to qualitative performance and design attributes. The reviewer said it was not clear what the different architectures were and how they were rated beyond engineering intuition and judgement. It would be helpful for this methodology to be described rather than presenting a decision matrix that has so many rows and columns that it cannot be read. The reviewer said the process of evaluating different electrical vehicle architectures is complex and so a well thought-out evaluation process could be a very useful outcome from this project.

Reviewer 5

The reviewer said the pie charts point out energy consumption by various subsystems. However, there is no estimation/analysis that shows the saving opportunity from each subsystem and the overall/aggregate energy-saving opportunity. Approach: Does the machine need to be electrified to produce energy savings? It would be good to understand how much savings can be done just by modifying the current machine architecture and how much extra (if any) is based on the electrification. The reviewer noted this project's objective is to demonstrate 20% savings. Is there a line of sight to achieve it and at what cost? The PI outlined a high risk of getting the components needed for electrification. This may hinder the project pace, based on the future architecture and needed components. Is there an alternative plan?

Reviewer 6

Utilizing an entire budget period to instrument a machine and characterizing standard drive cycles is something that could be replaced by standard drive cycles presumably known by the industry partners in the given application. The proposed timeline is not reasonable nor planned and executed properly.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer said that progress appears to be good.

Reviewer 2

The reviewer commented that modeling work has been quite good, with development of a solid-looking modeling platform to guide the project into hardware selection and development. Unclear if the team has identified any specific hardware, or control approaches, etc. Seems like there is a great deal of work to do in less than 50% of the remaining project time.

Reviewer 3

The reviewer remarked it is good to see the progress that has been made so far on the development of representative operating cycles and modeling of the baseline as well as electrified architectures. However, the lack of pre-existing information and field data may put the completion of some of the milestones at risk, but I trust the project team is exploring creative ways to keep the project on track.

Reviewer 4

The reviewer said that to date, the project achievements include drive cycle determination and a machine model. The details of the model, objectives, and its structure are unclear and results/conclusions are limited or of very basic nature.

Reviewer 5

The reviewer said this project made good progress in getting the machine cycle defined and the machine virtual model validated. The spreadsheet (Pugh matrix) is not readable and it is not easy to understand the decision-making process based on it. The reviewer noted the team seems to have ruled out a full BEV, but their selected architecture "schematic" does not make it clear where the engine power is used. Please elaborate on P0 and P3 architectures.

Reviewer 6

The reviewer noted that researchers have faced a number of obstacles to making progress on this project, and they again face the challenge of long lead time of electrification components. However, they have been persistent in moving the project along to achieve the project milestones. The lead time issue is concerning as all of us have been facing it. The reviewer said the team should plan multiple contingencies for this issue.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said the researchers appear to have a strong team that includes end user and component suppliers.

Reviewer 2

The reviewer said it looks like the OEM and other team members are starting to contribute to the project.

Reviewer 3

The reviewer remarked there is broad based collaboration between a university, OEM, and critical component suppliers with clearly defined contributions, but will require more co-ordination across the project partners to overcome some of the logistics as well as critical component procurement challenges.

Reviewer 4

The reviewer remarked from the presentation, it was clear that the partnership is little to non-existent. It is unclear what each of the partners tasks are.

Reviewer 5

The reviewer cannot really tell how much collaboration has happened to date.

Reviewer 6

The reviewer said there is a set of nine collaborators, which brings a good set of resources to the project. There were bullets outlining the contribution of each collaborator, but the description could have been clearer. The frequency of collaborator meeting and interaction should be described and provided to the reviewers. There was an issue with the baseline machine arriving at the wrong time, which delayed and affected the project. These types of issues should be addressed with better interactions between the collaborators.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said the remaining work plan is quite good and well-focused. It is moderately well defined but there are a great number of details which are not at all discussed. Integration, controls, etc. are massive challenges and they are not really discussed at all.

Reviewer 2

The reviewer said the design/build portion of the project appears long (FY 2023 and FY 2024) leaving less time for controls and calibration, which always takes longer. This reviewer encourages the team to accelerate that and leave more time for development and use of the hardware.

Reviewer 3

The reviewer remarked the plan is not tangible, nor did the presenter show any details on what the work scope is for the upcoming project budget periods.

Reviewer 4

The reviewer said the project milestones and approach are defined but the proposed future research activities do not have clearly defined timelines, and it is not clear to this reviewer whether the project team has a pathway for achieving the 20% fuel consumption reduction goal.

Reviewer 5

The reviewer said it looks like the team will demonstrate what they said they would demonstrate; what they demonstrate will be beneficial for the machine and the OEM of that machine, but the focus may be too narrow, and it is questionable how much it will be replicable to other machine types.

Reviewer 6

The reviewer remarked the proposed future research generally aligns with the timeline and milestones, but the task could have been more clearly stated as well as the purpose that the team seeks to achieve. Given the past challenges that the project faced, there are some concerns about retrofitting a vehicle and getting the testing done to achieve the milestones within the timeframe that was outlined.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer remarked the project focus on demonstrating 20% reduction in fuel consumption in off-road material handling equipment is critical for the industry and will support the overall VTO objectives for advanced engine and fuel technologies.

Reviewer 2

The reviewer said the project is relevant in that these applications have potential for large fuel savings and emissions reductions.

Reviewer 3

The reviewer said this project has good relevance to VTO objectives.

Reviewer 4

The reviewer remarked the project is targeting energy improvements and adding electrification as a means to achieve it. It is not easy to see how the project results and the techniques used will be useful to a broader spectrum of applications.

Reviewer 5

The reviewer said yes, this project demonstrates potential in reducing energy and emissions using electrification of a material handler. The knowledge gained from this work will be extendable to other off-road vehicles.

Reviewer 6

The reviewer remarked due to the basic nature of the project and the lack of progress overall, the project is not relevant.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said resources seem adequate for the project.

Reviewer 2

The reviewer commented the budget appears to be good for the project scope and targets.

Reviewer 3

The reviewer said that based on the 30% completion rate reported with budget period 1 milestone activities completed, budget period 2 milestone activities on-track, and budget period 3 milestone activities not started, the resources should be sufficient for the project to achieve the stated milestones in a timely fashion based.

Reviewer 4

The reviewer noted the team has an OEM, many suppliers, as well as end-users for machine testing engaged (according to Slide 13). There is no easy way to judge their level of engagement, but the reviewer trusts that they will be providing substantial support for this project to move ahead.

Reviewer 5

The reviewer said the project brings together an excellent team combined with good DOE and partner resources that should enable the achievement of the stated milestones in a timely fashion.

Reviewer 6

The reviewer said the amount of resources provided relative to the amount of outcomes so far is absolutely excessive.

Presentation Number: ace163
Presentation Title: Ducted Fuel Injection and Cooled Spray Technologies for Particulate Control in Heavy-Duty Diesel Engines
Principal Investigator: Adam Klingbeil, Wabtec

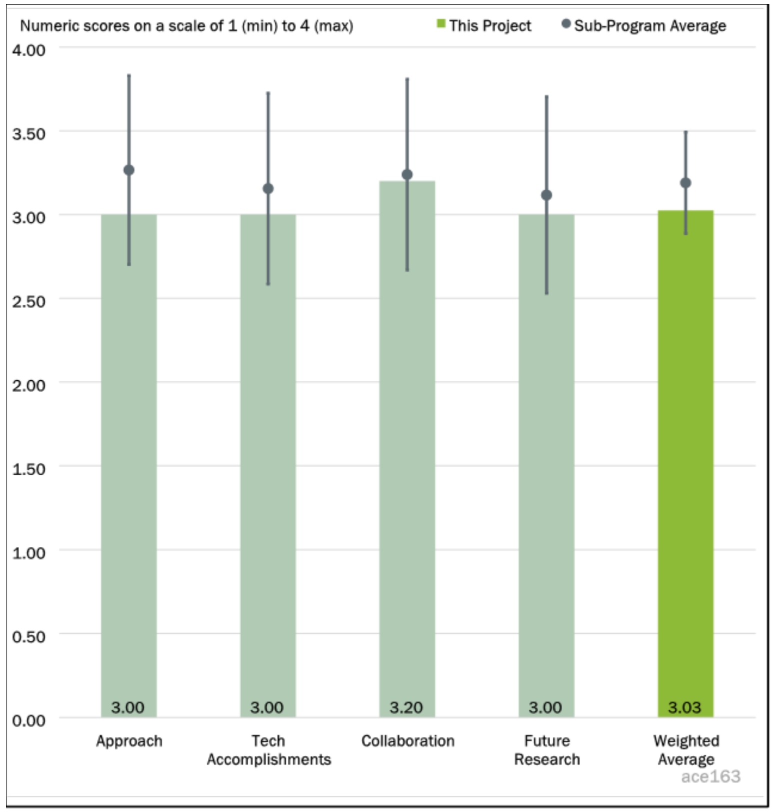

Figure 1-19 - Presentation Number: ace163 Presentation Title: Ducted Fuel Injection and Cooled Spray Technologies for Particulate Control in Heavy-Duty Diesel Engines Principal Investigator: Adam Klingbeil, Wabtec

Presenter

Adam Klingbeil, Wabtec

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

It appears to this reviewer that the qualitative effects of ducts can be explained, but a detailed quantitative-fundamental explanation is missing. Additional efforts which include the fundamental aspects of this technology will be useful.

Reviewer 2

The reviewer said this is a nice collaboration between Wabtec, SNL, and Southwest Research Institute (SwRI) to develop a retrofittable ducted fuel injection (DFI) design—called Cooled Sprays—for heavy-duty diesel engines. In my opinion this is a high risk, high reward endeavor. DFI has been demonstrated to drastically reduce particulate emissions in a way that breaks the classic soot NO_x trade off. Doing so allows one to adjust the engine to more efficient injection timings, and furthermore it has been shown to show the same reduction potential when using oxygenated low net carbon fuels, yielding extremely low levels of criteria pollutants. The reviewer noted the objective of this work is to establish the understanding and propose a pathway for moving this concept from successful laboratory operation into real world application.

Reviewer 3

The reviewer said the project concept is novel and is presented as a potential reduction for soot emissions. Some of the barriers for the technology are brought up is alignment of the channel to the injector hole. There would appear there are MANY more barriers: UHC owing to the close channel geometries, additional surface areas, and the interruption of the flow due to the added geometry. The reviewer cited that possible improvements on the project plan may be: Test fixtures could be re-thought to dramatically control the alignment issues noted; manage the alignment in multiple holes; improve or document the measurement scatter (NO_x and particulate matter (PM]); report on other emissions (UHC) and fuel economy for each test point; and align the metal and optical engine configurations as they are very dissimilar now.

Reviewer 4

The reviewer did not understand the lack of CFD work on this project. There are multiple questions that could be answered with simulation instead of extensive experimental work (e.g., what is the connection between the passage diameter and spray opening angle at various conditions).

Reviewer 5

The program proposes a development approach incorporating experimental evaluations of DFI on an optical engine, and of the cooled spray (CS) concept in a metal engine, then using that data to develop scaling relationships for the DFI/CS concept(s) to apply them more broadly across engine platforms. This is a reasonable approach to advancing understanding of DFI/CS. However, exclusively using an experimental approach to develop information for the scaling exercise seems like a very low efficiency approach, given the broad design space for injector, ducts, and combustion system. It would be helpful to understand the breadth of the design space being considered, and the approach to narrow it towards an optimum configuration. Using simulation would seem to significantly improve the process.

The reviewer said there is a mismatch between apparent scaling exercise work and the end-of-year milestone to collect performance results "in at least 2 updated CS designs" and program target indicating "3-5 more CS/nozzle concepts" in 2023. If the scaling laws are solely developed from experimental data, this seems like a low number of configurations given the degrees of freedom for the duct designs.

The reviewer noted that for a diesel engine, the efficacy of an injector design is coupled to the design of the piston bowl, and often the two are co-developed as a single combustion system. The program here does not appear to be considering design changes to the piston in conjunction with the new injector concept. This appears to be a gap, especially because the optical engine appears to have a different piston design altogether. It is challenging to see how either an optimal injector configuration, or strong scaling relationships, will result without optimizing piston and injector together, and between the optical and metal engines.

The reviewer was surprised to see a 1 mm diameter duct as one of two ducts being evaluated. This is smaller than the ducts the SNL has published on previously, even though the injector orifice diameter is quite a bit larger than what is used on the SNL engine. On the surface, this raises concern about the design selection process.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer said that accomplishments are excellent. A redesigned DFI concept has been developed and produced. It is being tested in both optical and metal engines. As expected in any such high risk, high reward endeavor, there have been some good as well as disappointing results. The researchers are learning from these results and are making progress consistent with their work plan.

Reviewer 2

The reviewer said excellent results (mostly experimental) have been obtained. The duct design and alignment work are very good, and the early experimental results are very interesting.

Reviewer 3

The reviewer said the presentation is unclear as to whether the experiments take place with DFI (ducted) or CS. A more detail explanation of the test geometries could be given with simple estimates of flow velocities, entrainment ratio, etc. It is also unclear whether the CS require fresh air injection into the cylinder, the schematic of Slide 4 shows what may a appear to be a re-entry point upward. How extensive has the present configuration been studied, what other arrangements are possible, what would be their pro-cons?

The reviewer said initial data shows promise, but it is limited to the lower rpm case. What is the benchmark the authors are looking to? How does this compare with competitive technologies in this same space of NO_x-soot tradeoff (examples may be effect of increased injection pressure, bowl-injector match optimization)?

Reviewer 4

The reviewer said the project is in initial phases, and this reviewer is afraid that expectations are too big for what the project will actually achieve.

Reviewer 5

Project has been making technical progress, and key milestones appear on track. It was not clear from the written or presented material how much design or development effort went into creating the prototype DFI/CS injector systems that were evaluated on the metal engine. Engine evaluation of two different configurations of nozzles across multiple operating points has been completed, along with a detailed effort to quantify and spray alignment with the prototype hardware.

Information from the metal engine experiments was incomplete, with results simply focused on soot emissions. NOx emissions were only reported at one condition, and hydrocarbon (HC) emissions and impact on efficiency impacts not covered, leaving a clear gap in understanding of the technical progress and performance demonstrated.

The importance of alignment between duct and injector orifice was explored, with substantive effort on developing techniques for quantifying the alignment. This has been identified as a key are for future work to establish better alignment on the ducts, especially challenging with a multi-hole injector.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said it appears to be a strong synergy of team members.

Reviewer 2

The reviewer remarked the team could have taken advantage of a CFD partner. It could have provided notable insight as to the fundamental dynamics taking place.

Reviewer 3

The reviewer commented good collaboration between the various parties involved in the project.

Reviewer 4

The reviewer said the combination of Wabtec, SNL, and SwRI is a strong and synergistic collaboration.

Reviewer 5

The reviewer noted that the presentation identified two partners for the program: SNL, who conducts DFI experiments in an optical engine platform, and SwRI for the metal engine testing. The role of SNL is quite clear, and is a key partner for any efforts in the ducted fuel injection space. The extent of SwRI's effort or project involvement beyond engine testing and data processing was unclear; are they only a test contractor, or are they adding additional value to the program?

The reviewer was surprised to see, given SNL as a partner, the appearance that not all learnings from the DFI studies at SNL were transferring to this program. Duct designs and geometries are inconsistent with the information SNL published previously. This raises questions on the effectiveness of this part of the partnership. The reviewer said key programmatic gaps in engine modeling and simulation could be addressed by the additional of project partners such as universities or national laboratories. Further, the challenges in manufacturing components with very specific alignment might be an opportunity to engage additional program partners to assist.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said future work is very clear and milestones clearly identified.

Reviewer 2

The reviewer said proposed future research is adequate.

Reviewer 3

The reviewer commented the proposed future work, at a high level, is in alignment with a path towards achieving the program goals and targets. However, achieving the goals stated with the limitations on the work being conducted—including lack of CFD/simulation effort, relatively small set of configurations being tested, only redesigning the injector and not the full combustion system—raise concern on whether the project will achieve its targets.

Reviewer 4

The reviewer said it appears that the future empirical work is based on educated insights. I feel the weakest part of this project is the lack of companion modeling. Why are the results so good at low speeds, but worse at high speeds? Modeling could likely help answer this question, and then guide the duct design directly. Please also include efficiency, emission and durability results in future experiments.

Reviewer 5

The reviewer remarked the researchers are learning from their results and making the appropriate adjustments to their work effort. It would be highly desirable to include a CFD effort to perhaps gain additional insights into the fundamentals governing their successes and their disappointments. The team currently does not have the resources for this, but in my opinion, it would increase the likelihood of success.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer commented the pursuit of lower soot in the CI context is excellent.

Reviewer 2

The reviewer said the novel concept would provide a means to improve the fuel air mixing in an engine with potential large reduction of soot formation, and therefore improve cost and durability of these platforms.

Reviewer 3

The reviewer said the project is supportive of the overall Advanced Engine and Fuel Technologies objectives to generate knowledge and insight necessary for industry to develop the next generation of engines. The project seeks to advance the state of technology and understanding of an advanced clean diesel concept that reduces engine-out criteria pollutants, in this case particulates. It is also well-focused on moving the DFI concept towards production viability in a market sector that is challenging to electrify, and constrained on solutions for emissions control.

Reviewer 4

The reviewer said decreasing diesel emissions is an important part of the VTO mission.

Reviewer 5

The reviewer referred to prior comments.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said resources appear to be sufficient.

Reviewer 2

The reviewer said resources are adequate. The team employs good engine test facilities, though it could have utilized stronger input from modeling.

Reviewer 3

The reviewer said a funding level of $1 million year seems appropriate for the scope of work being executed.

Reviewer 4

The reviewer said it is difficult to comment on resources when the available funding is so small but experimental cost went through the roof in terms of expenditures.

Reviewer 5

The reviewer referred to prior comments.

Presentation Number: ace166
Presentation Title: New Two-Cylinder Prototype Demonstration and Concept Design of a Next Generation Class 3-6 Opposed Piston Engine
Principal Investigator: Fabien Redon, Achates Power

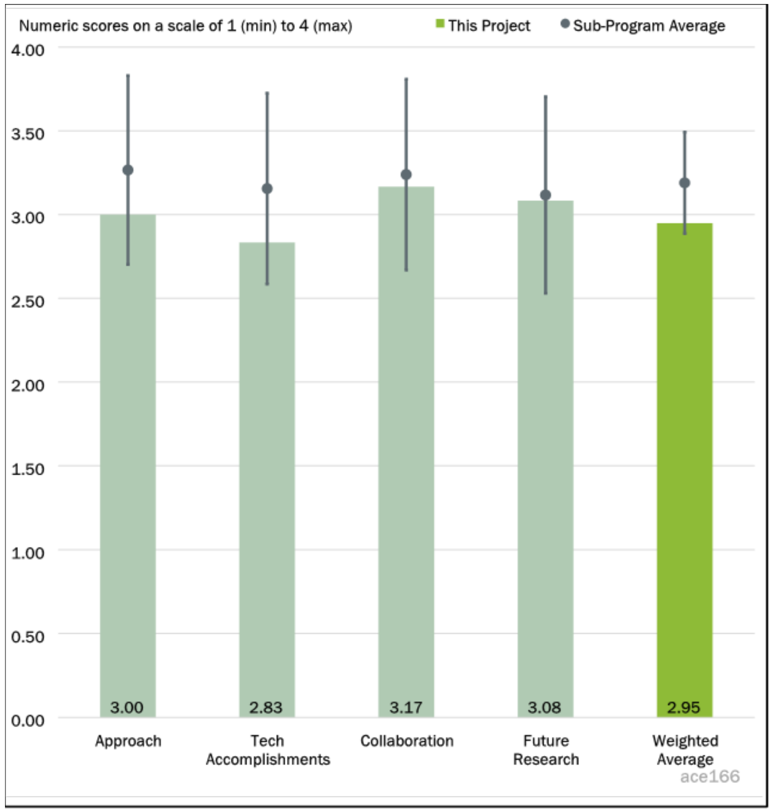

Figure 1-20 - Presentation Number: ace166 Presentation Title: New Two-Cylinder Prototype Demonstration and Concept Design of a Next Generation Class 3-6 Opposed Piston Engine Principal Investigator: Fabien Redon, Achates Power

Presenter

Fabien Redon, Achates Power

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 17% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

Enhancing the cost-effectiveness of engines is a pretty big challenge. The opposed piston two-stroke (OP2S) architecture does not produce the cost-savings that are claimed by the authors. The cost savings only hold true if one starts a factory from scratch and uses that factory to only fabricate OP2S engines. The upfront cost of the brand-new factory will be substantial and will take time to amortize. If one needs to re-configure a current factory, there will be no cost-savings at all between re-tooling and scrapping cylinder head and valve assembly lines, recasting cylinder blocks and liners, and re-sourcing injectors and turbochargers/superchargers. A complete architecture change is a very unusual way to promote “cost-effectiveness”, even if there is a slight reduction in aftertreatment cost.

Reviewer 2

The work addresses the noted barriers and those barriers are linked to the barriers of the VTO and 21st Century Truck Partnership (21CTP) Blueprint barriers. The presentation could more explicitly link to the 21CTP Blueprint which includes improving efficiency by identifying and addressing heat transfer losses.

Reviewer 3

The overall approach of simulation and prototype experiments is sensible for this particular engine architecture, for this specific project. An overall positive impact on the fuel efficiency and emissions compared to all combustion engines may not be evident from this work unless engine data are collected in standard test cycles and compared to the EPA database.

Reviewer 4

The project replaces typical diesel engines with opposed piston engines which, per the presentation, does not have the same barriers as the diesel engine.

The targets are specified and this is almost the end of the project but it is not clear if the targets are achieved or will be achieved by the end of the project.

Reviewer 5

The timeline is aggressive for this project given the 2 years to demonstrate superior efficiency and emissions from a two-cylinder OP2S in comparison to a benchmark OEM engine. To date the project is leaning heavily on simulations and the degree to which barriers will be addressed is better assessed after there is some experimental data. However, generally, this OP2S project does address barriers for today's four stroke engines relative to the OP2S.

Reviewer 6

The work approach is generally good at developing a workflow to optimize combustion, simulate combustion to optimize swirl and gas exchange, and to use Gamma Technologies - Power (GT-Power) models to simulate efficiency over a wide operating regime. This reviewer does not see a need to help simplify the open cycle simulations—the 16-day simulation is certainly impressive, but is unsustainable for iterative work. The team should be using these complex simulations to develop simplified models that can produce a substantial amount of the necessary information at a fraction of the computational cost. For engine development work, developing an approach to help with the open cycle simulations that is less computationally intensive is warranted.

It does not seem like the barriers that are being addressed in this project are really new barriers - these have all been addressed in previous versions of the OP2S engine, and are being scaled to a different cylinder count.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The simulation work done by both University of Wisconsin (UW) and Clemson University shows some promise in being able to meet ultra-low nitrogen oxides ($ULNO_x$) emissions through some combustion improvements and using conventional aftertreatment. However, the minimum BSFC shown on Slide 9 is very suspect, in the sense that a 6% improvement in BSFC is substantial and not many details were shown in the slide as to why that configuration was so much better on fuel efficiency than the baseline.

There does seem to be significant progress in the areas of two-cylinder design and procurement of hardware. It will be very interesting to track the progress of the two-cylinder work as it progresses.

Reviewer 2

The reviewer said CFD and GT-Power modeling for scaling the design to the target class have had good progress, and all parts for the new engine besides the electric turbocharger (e-turbo) have been received. Partner progress on vehicle level modeling is well underway.

The status of the model predictive control and what methods and validation are being used there were not clear in the presentation.

Reviewer 3

The progress in combustion simulation, GT-Power models, and fabrication of engine is commendable. COVID-19 impacts are acknowledged. There is a nice comparison of fuel efficiencies in vehicle simulations over known drive cycles.

Reviewer 4

Progress to date is leaning heavily on simulations that were calibrated with a different OP2S engine (three-cylinder) than the project's targeted two-cylinder OP2S. The project is executing well against the project plan as evidenced by significant modeling and simulation, and design work on the two-cylinder OP2S. The next four months of experimental work are arguably the most critical to the project.

Reviewer 5

There has been good progress made on optimization of the combustion chamber, open cycle simulations, and using GT-Power to predict the engine performance. It would have been nice to see an engine build, but COVID-19 and supply chain delays associated with the air handling equipment are reasonable and understandable.

Reviewer 6

It looks like the university partners are progressing really well but it is not clear what the industry partners are doing. Even though there seems to be a lot of progress at the universities, surprisingly there are not too many publications. Of course, some information is protected but the information on the slides could result in multiple papers.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This team seems well-constructed to address the issues in this project. There is a good combination of industry and university partners.

Reviewer 2

This is a good collaborative team with partnership with industry and university. There are clear contributions from Clemson University, UW, and Isuzu Technical Center of America.

Reviewer 3

The involvement and contributions by the partners are adequately presented and explained. Partners appear as substantial contributors.

Reviewer 4

It is very apparent the project has strong collaborations across the two universities and the OEM. This is evident by the sharing of engine simulation results and the fuel economy analysis with OEM guidance.

Reviewer 5

There appears to be a good project team with delineated workflow and the correct expertise. The contributions from the university partners are clear, and all partners appear to be producing results as part of this project.

Reviewer 6

It looks like the universities are doing the bulk of the work and coordinating with each other. It is not clear what the industry partners have accomplished in the last 2 years.

Question 4: Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1

Building and testing a two-cylinder engine is the only way to validate the proposed concepts of this project. The assumption is that a family of multi-cylinder engines (2, 3, or 4) of the same geometry would be cheaper to make than 3-cylinder versions of different displacement engines.

The target seems achievable. It would be good to understand how validation of the vehicle systems simulations and drive cycle estimates will be completed.

Reviewer 2

The reviewer recommends the project to consider adding engine data over Federal Test Procedure (FTP) and (SET cycles. Validating achievement of $ULNO_x$ will be important.

Reviewer 3

A lot of work is proposed for the last part of the project. The reviewer expresses uncertainty in whether all of the work can be done in the remaining time.

Reviewer 4

It is very clear the next phase of the project will yield the most useful results based on engine testing. One recommendation is to explore as many engine operating points as possible versus a couple or few selected points. This additional information could be very valuable to the project team and the industry in general.

Reviewer 5

The project is wrapping up at the end of 2022. The remainder of the project focuses on engine validation and vehicle simulations, which is appropriate for this stage of the project.

Reviewer 6

The pathway to complete the project was clear with noted collaboration with Clemson University after shakedown. It is not clear what role remains for UW.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This project is relevant to advancing DOE goals in lowering $ULNO_x$ and reducing GHG by improving fuel efficiency.

Reviewer 2

The project directly supports VTO subprogram objectives around increasing efficiency for engine systems for medium- and heavy-duty vehicles.

Reviewer 3

In general, efforts to improve engine efficiency are always relevant for improved freight efficiency and reduced carbon dioxide (CO_2) emissions. The target of 10% fuel economy improvement over a Class 4 Isuzu vehicle over the customer derived real world drive cycles has an imprecise baseline and is not really adequate in the big picture.

Reviewer 4

This project is addressing barriers towards the development of ICE with low emissions, reasonable cost, and good fuel economy. It is focused on improving indicated thermal efficiency (ITE) while trying to maintain good emissions performance with an advanced two cylinder engine that is outside the norm compared to four stroke engines.

Reviewer 5

This project is focused on reduced fuel consumption, which is in line with DOE VTO goals.

Reviewer 6

This project was funded before the recent change of direction within the program.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The resources for this project appear to be sufficient to obtain a successful outcome.

Reviewer 2

Resources seem sufficient for achieving the stated milestones.

Reviewer 3

In view of past and ongoing government support to this engine's development, the cost share should be higher. The reviewer suggests comparing to cost share in SuperTruck projects.

Reviewer 4

The project seems properly resourced to hit project objectives. This reviewer's only suggestion is to perform as much engine map testing as possible within the budget.

Reviewer 5

Resources appear to be sufficient. All project partners are producing results, and project delays appear to be minor and unrelated to funding.

Reviewer 6

The role of the industry partners is not clear which makes it difficult to comment on the resources.

Presentation Number: ace169
Presentation Title: Greatly Reduced Vehicle Platinum Group Metal (PGM) Content Using Engineered, Highly Dispersed Precious Metal Catalysts
Principal Investigator: Yong Wang, Washington State University

Presenter

Yong Wang, Washington State University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

75% of reviewers felt that the project was relevant to current DOE objectives, 25% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

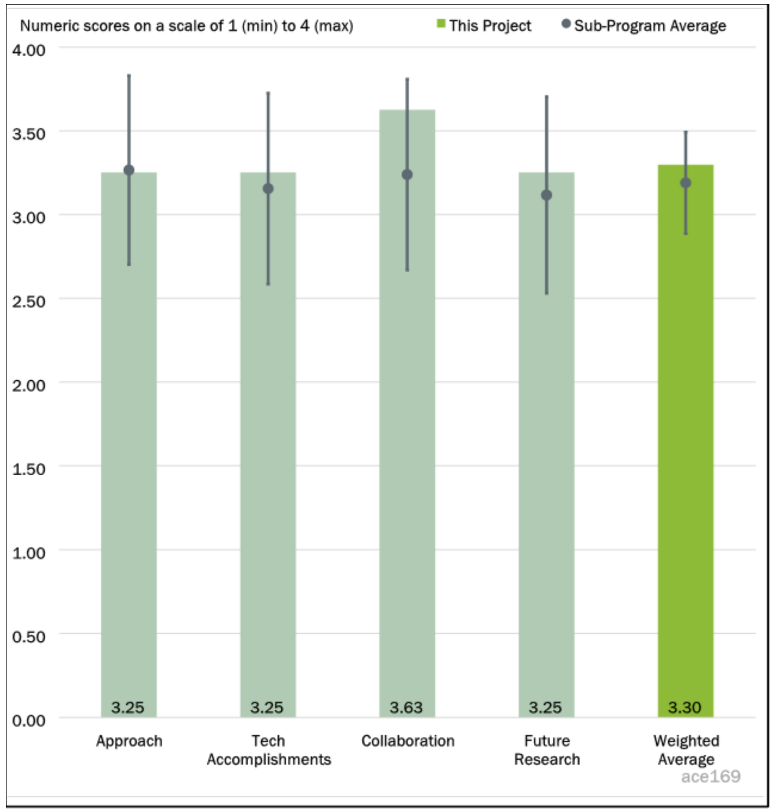

Figure 1-21 - Presentation Number: ace169 Presentation Title: Greatly Reduced Vehicle Platinum Group Metal (PGM) Content Using Engineered, Highly Dispersed Precious Metal Catalysts Principal Investigator: Yong Wang, Washington State University

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The project appears well designed after 1.5 years of performance and has a good focus on appropriate technical barriers. Looking at Rh, as it is the most costly metal, is also appropriate. Even though there is likely less Rh in the overall catalyst system compared to other metals, the total cost of Rh is probably more than Pd, so the approach is reasonable.

Reviewer 2

This project is well-designed and well-planned to achieve enhanced TWC performance with single atom PGM/ CeO_2 catalysts in a real-world application.

Reviewer 3

The team has clearly tried multiple synthetic strategies to achieve sufficient performance with reduced PGM loadings, and made excellent use of their characterization tools to understand why some formulations look promising while others fall short. However, it is not clear if the synthetic strategies they are pursuing can be scaled up to industrially relevant processes; it would have been better to use scalability as a factor in developing and down selecting synthetic pathways. Also, the baseline catalysts were not well-defined - it is not clear if they are production TWC materials or something else.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The team has made excellent progress in modifying their synthetic strategies with Rh-based catalysts, although they have not yet achieved performance parity with the baseline materials. Also, the progress on Pd was unclear from the presentation, as the only data set included in the presentation was a single light-off curve conducted in the absence of water in an undefined aged state (which probably means unaged). Pd must be addressed to significantly reduce PGM loading in TWCs.

Reviewer 2

Isolating deposition of Rh on only CeO_2 in the support is an excellent achievement. The observation that trapping sites are better in nanoparticles of ceria versus isolated cerium (Ce) is not surprising based on the literature. Looking at the effect of ceria particle size on successful and efficient trapping and maximal use of Rh (and Pd) would be useful to explore.

The production of 100g of catalyst with the new approach is also a significant accomplishment.

Reviewer 3

The project has shown good progress in developing a potentially scalable method for supporting SACs on ceria which are then supported on alumina.

The project would clearly benefit from kinetics and mechanistic analyses. While the oxidation of CO on SACs anchored by ceria is intuitive, the nitrogen monoxide (NO) reduction is not. Rate measurements and potentially exposed metal area measurements would help to elucidate the pathways for N_2O, NH_3, and molecular nitrogen (N_2) formation. Specifically, how does NO get activated on a single Rh atom? Does the NO dissociate on Rh atom with atomic oxygen (O) migrating to ceria? Or does the NO dissociate on the ceria? These questions are pertinent not only for advancing the science but also in assessing aging and scaling up the catalyst. The project would clearly benefit from kinetic and monolith reactor modeling components.

Reviewer 4

The response to the reviewer comments from last year regarding the performance were not adequately answered—either in words or in work.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The project team is excellent, and includes University of New Mexico (UNM), Washington State University (WSU), and PNNL. It shows in the results. Excellent collaboration for minimizing the use of PGM by making near-SAC catalysts that are reducing the metal content in the catalyst by a factor of at least five.

Reviewer 2

This is a really strong team with no gaps. The only area to work on is the aforementioned kinetics. There is a nice balance of academic, national laboratory, and industry partners.

Reviewer 3

The team has an excellent mix of universities, national laboratories, and industry partners including both an OEM and a catalyst supplier, and appears to have all the capabilities needed to succeed. The coordination across the team was documented and appears to be good, although it would have been interesting to hear a bit more about who was responsible for the work completed to date.

Reviewer 4

The team represents a good cross-section of the industry, suppliers, national laboratories, and universities.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The future research goals to be achieved will depend on a good interaction between PNNL, WSU, and UNM with BASF. The reviewer is curious to see how that works out.

Reviewer 2

The team has identified the right paths for next steps.

Reviewer 3

All the steps proposed in the future work are necessary to achieving success. However, it is not clear that the team has defined a pathway to scale up the SAC synthesis process to generate sufficient material for an engine/vehicle demonstration of the most promising formulation(s), or to define an industrially relevant pathway to catalyst production.

Reviewer 4

It is unclear how the future work plan will achieve the project goal. There is still a lot of focus on fundamental, bench-scale samples (powders, cores) and there is a large difference between that scale and demonstration.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The successful implementation of this proposed emission control system will lead to the most fuel-efficient pathway to meeting required emission control standards.

Reviewer 2

This project is a great fit with VTO.

Reviewer 3

The project is relevant to DOE goals for emissions reduction.

Reviewer 4

It is not clear how this project addresses the DOE VTO mission of decarbonizing the transportation sector.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The range of tools available to solve the issues in this project are quite sufficient in the laboratories at PNNL combined with UNM, WSU, and BASF.

Reviewer 2

There is a good balance of resources.

Reviewer 3

The project has a substantial budget, although the reviewer worries that the work plan and funding are front loaded toward the universities and national laboratory such that there will not be enough resources remaining at the end of the project for successful scale up and demonstration at the engine/vehicle level.

Reviewer 4

Resources seem sufficient for this project.

Presentation Number: ace170
Presentation Title: LLCF Effects on Emissions Control Catalyst Performance and Durability
Principal Investigator: Sreshtha Sinha Majumdarm, Oak Ridge National Laboratory

Presenter

Sreshtha Sinha Majumdarm, ORNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers felt that the resources were sufficient, 50% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

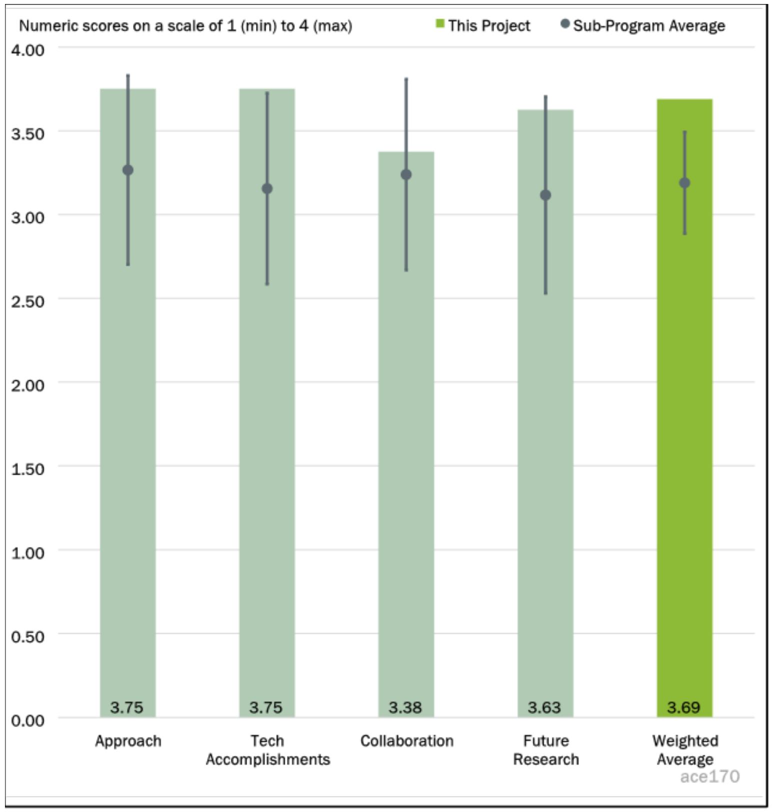

Figure 1-22 - Presentation Number: ace170 Presentation Title: LLCF Effects on Emissions Control Catalyst Performance and Durability Principal Investigator: Sreshtha Sinha Majumdarm, Oak Ridge National Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer thinks this is a really excellent project. Low life-cycle carbon fuels (LLCFs) are a fast way to decarbonize the transportation industry. Fungible LLCFs could be deployed immediately through existing HC fuel infrastructure. With these fuels - there is no need for complete fleet turnover - and it would greatly reduce the pressures on the supply chain for a variety of materials. The key barrier to this deployment is understanding the combustion, emissions, and aftertreatment potentials of these fuels.

Starting with a questionnaire to stakeholders allows this project to start with an industry-relevant perspective. This reviewer admits surprise to see that ammonia scored as well as it did across the sectors—since there are significant safety issues related to it. There is a strong experimental plan, making good use of ORNL experimental facilities and experience. The timeline seems aggressive, but the project is on track. There is a good range of LLCFs in the study.

Reviewer 2

This is a rather straightforward project in terms of concept. The team is evaluating how well/poorly different primary pollutant components from different fuel sources are oxidized over a standard DOC. The fuel and emissions choices are based on previous Co-Optima findings. With common engine platforms for a variety of fuels, knowing how a common emissions system might handle the emissions from those fuels is critical. This project begins to address that concern.

Reviewer 3

Using the methods and skills developed in this ORNL group to good advantage, this project is learning which LLCF would be good choices for decarbonization of engine applications that are difficult to electrify, and learning their emissions control issues. This approach is also wisely guided by a survey of companies that have indicated what they are most interested in learning about, and with the main catalyst of interest being a DOC.

Reviewer 4

The ORNL-led project focuses on low carbon fuels for difficult-to-electrify engines. This is an important scouting project, hopefully to define an expanded investment by DOE VTO.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The project has recently started and is making progress. The oxidation of a surprisingly large number of hydrocarbon types has already been evaluated. The rig being used has been used consistently in the past, and thus there is already confidence in the results.

Reviewer 2

The light off (LO) temperature for oxidizing LLCF fuels over a DOC has been analyzed and the temperature depends on the structure of the fuel. The alcohols are good choices, but they also partially oxidize to aldehydes at low temperatures at the same time that alcohols are being completely oxidized.

Reviewer 3

The project has made good progress in seeking input, defining the approach, and conducting initial experiments. The LO experiments would benefit from a more fundamental look at oxidation catalysis. There is a large literature on PGM-catalyzed oxidation of various hydrocarbons. It does not appear that the investigators have done a literature survey.

The first step in obtaining LO temperatures is fine. However, looking ahead, the issue of inhibition needs to be examined in terms of CO inhibition of HC, and potentially HC inhibition of CO. NO adds a further complication. In other words, the common exhaust constituents CO and NO can drastically impact the LO temperature. Such effects are known and reported in the literature.

Reviewer 4

It is not surprising that the DOC reactivity is dependent on the HC species—this is something the aftertreatment community has long known for petroleum HCs - however, identification of aldehyde intermediates from methanol, ethanol, and isobutanol with speciation is a key piece of information that will be important for understanding if the aftertreatment community will be able to meet emissions reduction goals.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

From the presented material, it is apparent that the industry partner is providing input. The role for PNNL or that PNNL is playing is unclear.

Reviewer 2

The partners for this project are excellent choices, since PNNL and ORNL have already worked on several projects together and Caterpillar would be a major user of LLCF fuels in their off-road products. Another off-road partner, such as John Deere, or a maritime partner, such as Maersk, would be other partners to consider, if they might be interested.

Reviewer 3

The project team has received excellent input to frame the problem with respect to LLCFs. The involvement of Caterpillar is a positive given its position as a leader in off-road. The project would benefit from a more fundamental perspective, potentially with an academic partner.

Reviewer 4

The reviewer would have liked to see university collaboration - though the timeline of this project makes that tough. The reviewer is not sure what PNNL brings to the project and suggests considering consolidating resources to just ORNL for this project.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The first proposed part of the plan, aldehydes and alternate oxidation catalyst materials, is solid. The other parts are too vague to evaluate. Also, how will cross-interferences between hydrocarbons be evaluated?

Reviewer 2

Excellent future research challenges are included, since they directly relate to known future needs, particularly for eliminating aldehyde emissions through system controls or an improved catalyst with, or as part of, the DOC.

Reviewer 3

This reviewer would have liked to see some of the issues around inhibition, kinetics, and modeling considered.

Reviewer 4

The reviewer thinks this is an interesting opportunity to consider catalyst formulations to deal with the aldehyde intermediates. Perhaps a partner like Umicore/BASF/Johnson Matthey would benefit to be part of this work?

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This is a highly relevant study given the push towards decarbonization.

Reviewer 2

This program is relevant for emissions control from future engines, that will be running off a wide variety of fuel sources. It directly and nicely ties to the Co-Optima program.

Reviewer 3

This project has great relevance for the areas that it applies to. Assisting in the decarbonization of fuels is key in this area. In a more detailed sense, the details of how the real-world systems behave and guide research is very important as suggested. This reviewer would suggest renewing this project based on the important area it covers, which could end up expanding into other fuels, e.g., H_2 and NH_3, that could raise completely different challenges, but would be more clearly not adding any greenhouse gases to the environment.

Reviewer 4

Yes—this work supports the VTO goals of reducing CO_2 emissions. More work should focus on LLCFs/sustainable fuels, etc.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The funding does not appear to be sufficient to address issues not covered in the study.

Reviewer 2

Not enough money is being put into actualizable pathways for decarbonization. Sustainable fuels have a clear pathway to immediate adoption and could have significant impact on CO_2 emissions. Fungible fuels would not have any infrastructure delays. The reviewer thinks VTO should be investing more in this realistic area.

Reviewer 3

The resources appear appropriate. The reviewer would like to see more resources available, but in a manner to extend the project to include modeling, as that would ultimately be a great way for the results to converge—to be able to predict emissions as fuel blends change.

Reviewer 4

The resources at ORNL are especially relevant to this type of study, so for now the resources are very sufficient, unless other partners are added that may propose research in new areas requiring more staff.

Presentation Number: ace171
Presentation Title: Simultaneous Greenhouse Gas and Criteria Pollutants Emissions Reduction for Off-Road Powertrains
Principal Investigator: James McCarthy, Eaton

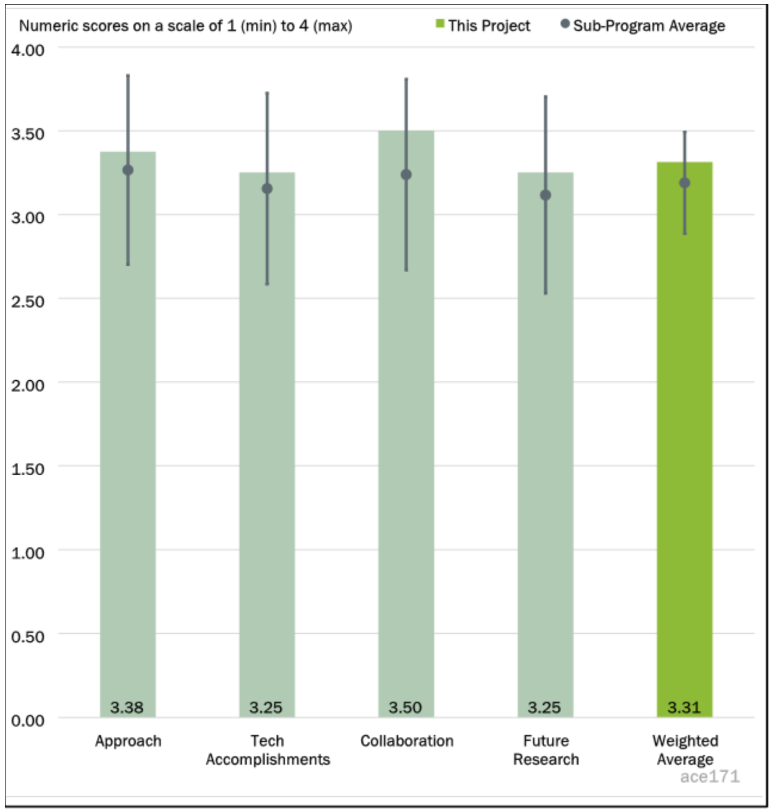

Figure 1-23 - Presentation Number: ace171 Presentation Title: Simultaneous Greenhouse Gas and Criteria Pollutants Emissions Reduction for Off-Road Powertrains Principal Investigator: James McCarthy, Eaton

Presenter

James McCarthy, Eaton

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The barrier is to build a high-efficiency, off-road future engine. The project will add significant technology to an off-road engine to improve the engine efficiency. The technology includes: variable valve actuation, high-efficiency turbocharger, electric EGR pump and new controls. They will also look at other parameters to improve efficiency, that have been documented for on-highway engines. The new exhaust aftertreatment will be developed to meet the future off-road emission standards with the goal of also improving the fuel economy. The project is well thought-out.

Reviewer 2

The project is only beginning, but the approach is sound and appears well thought-out.

Reviewer 3

This project is just starting but the technical content is clearly stated, a capable cross-organization team is identified, and the timeline appears realistic.

Reviewer 4

The reviewer thinks overall the project can be improved. The timeline is reasonably planned. A lot has been done for on-road diesel engines to achieve ultralow emissions. So, compared to the on-road engine, what are the major differences and barriers for off-road?

It is not very clear how CFD will be used for optimization. Is it for engine and aftertreatment system simulation, or just for aftertreatment system? What is the baseline N_2O emission? It seems that the baseline engine has an extremely high N_2O emission, otherwise, it is not possible to achieve a 3.5% GHG reduction.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The project was initiated in February 2022 and the team has already made good progress moving the project forward. The team has the baseline configuration agreed upon and know how to correct for GHG, submitted their project management plan, and created a program schedule. This reviewer is not sure much else could have been accomplished.

Reviewer 2

The project started three months ago. Good progress has been made such as assembling the team, deciding a baseline configuration and GHG correction using measured data and CFD simulations for a single-pass aftertreatment system with a DPF, submitting the project management plan, etc.

Reviewer 3

Again, the project is just starting, so there has not been a lot of progress made. But the team has completed what is appropriate at this stage; they have assembled the team, have a plan, and identified a baseline.

Reviewer 4

This project is just starting so there would not be significant technical accomplishments expected at this point. However, the plan is well laid-out as the technical approach is founded in prior work but with a focus on off-road applications. This reviewer feels this project has a high probability of success.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

Eaton has taken the lead in the project and so far has been doing the majority of the work. However, it is evident that Fiat Powertrain has been contributing in terms of supplying engines, providing input on test plans, and determining the overall schedule. Tenneco will become more involved when aftertreatment selection is required.

Reviewer 2

The project team consists of two major suppliers, a national laboratory, and a research institute, which have extensive experience in engine and aftertreatment technology development.

Reviewer 3

They have assembled a strong team. It would be helpful to understand in a bit more detail the roles for the various partners. For example, who is doing the aftertreatment system simulation and who is doing the overall system analysis and integration?

Reviewer 4

The project is just starting but this appears to be a well-rounded team with extensive experience covering the breadth of the technical approach. The inclusion of Eaton with strong engine and subsystem background, Tenneco with a strong aftertreatment background, ORNL and Southwest Research Institute (SwRI) with extensive systems/testing background, and OEM manufacturer Fiat Powertrain is a well-rounded and capable team.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The project plan is well laid-out and has a step-by-step plan to move forward. The PI and his team have been doing this for years so they understand what needs to be accomplished.

Reviewer 2

The program schedule defines the time of the future work, which seems reasonable and likely to achieve the proposed targets.

Reviewer 3

The technology content chosen is sensible as are the proposed next steps.

Reviewer 4

This project has a well laid-out and logical plan starting with definition of requirements and moving into test bed development and system testing and optimization. This reviewer recommends to make sure sufficient analytical modelling is performed to focus testing and avoid less beneficial hardware and calibration approaches.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

VTO is switching their focus from on-highway to off-highway and this project expects to improve the fuel efficiency by 10% while meeting the future off-road emission requirements.

Reviewer 2

The objective of the project is to research, develop, and validate AT system-level strategies capable of greater than 10% GHG reduction and greater than 90% NO_x reduction for off-road powertrains over multiple duty cycles spanning the diverse applications in the segment, while maintaining affordability and robustness to ensure economic viability. It supports the overall VTO subprogram objectives.

Reviewer 3

Reducing CO_2 and NO_x emissions are both relevant, as are reducing system complexity and cost (for a given performance).

Reviewer 4

Applying a well-known technology bundle to off-highway applications is a good use of these resources. The off-highway duty cycles and use cases are unique and this work needs to be performed to ensure the right technology bundles are developed for off-highway.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The team has sufficient resources for this project. The program schedule shows that the stated milestones can be met in a timely fashion.

Reviewer 2

The project's scope and timeline are very aggressive and the budget does not support this. However, Eaton has volunteered to provide additional support beyond the original commitment and, with the additional commitment of a second engine and resources, the project should be completed on schedule.

Reviewer 3

Time and budget are reasonable for the proposed plan.

Reviewer 4

Resources are appropriate for a project of this size. The total budget may limit the number of hardware combinations that can be tested.

Presentation Number: ace172
Presentation Title: Fast Simulation of Real Driving Emissions from Heavy-duty Diesel Vehicle Integrated with Advanced Aftertreatment System
Principal Investigator: Hailin Li, West Virginia University

Presenter

Hailin Li, West Virginia University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

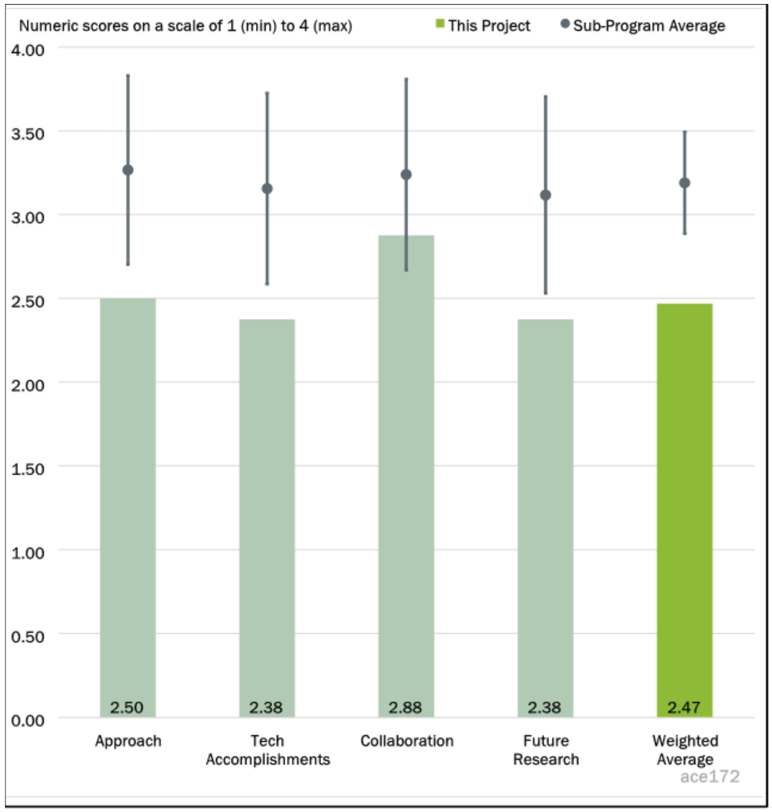

Figure 1-24 - Presentation Number: ace172 Presentation Title: Fast Simulation of Real Driving Emissions from Heavy-duty Diesel Vehicle Integrated with Advanced Aftertreatment System Principal Investigator: Hailin Li, West Virginia University

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The technical barriers on modeling real world emissions are being addressed. The overall approach is well suited—however, the details on the work approach and how this effort improves the current state-of-the-art and how the current limitations with such models are being addressed were not clear.

Reviewer 2

The reviewer thinks it is disappointing that the project started in September 2021 and the team still does not have the final contracts signed at West Virginia University (WVU). This has definitely delayed the project. The overall project definition, as this reviewer sees it, is that the project will collect engine experimental data and then validate a CFD model for emissions and exhaust temperatures. This will then be ported into the GT-Power Model and aftertreatment model. The entire model will be validated and finally should have the capability of running a heavy-duty (HD) vehicle driving simulation. As far as this reviewer knows, OEMs are performing similar analysis today in different pieces. What this work does is pull everything together and should allow the overall model to be run in GT-Power. The GT-Power model would then assist OEMs in their models and help improve aftertreatment systems.

Reviewer 3

The reviewer would like to see more details on how the models will be developed/validated, and the expected level of accuracy/predictive-ness. Model robustness/predictive-ness should include a range of parameters, including hardware-based items (e.g., compression ratio, piston bowl shape, etc.) and/or controls-based items (e.g., injection timing/strategy, EGR rate, etc.). How (and when) the aftertreatment model switches between the simple and detailed approach would also be a good detail to share.

Reviewer 4

Bureaucracy and staff shortages at WVU are seemingly preventing this project from getting started. Some work has started.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This project reviewed very early in the cycle. The full team meeting had not yet occurred at review time, but progress on models has already been made.

Reviewer 2

The contract is not officially signed, so not much progress has been made. The GT-Power models shown are pretty elementary and have not been exercised. In order to have a representative system, the project needs to identify every piece of the engine and this reviewer cannot tell if that has been done.

Reviewer 3

The project is only starting, so technical accomplishments are not really expected—yet. But this reviewer would have expected WVU to have processed the grant and all subs to be under contract. The fact this is not yet done is the reason for the “fair” score.

Reviewer 4

Some modelling work has started but the critical engine testing which will be used to correlate the models seems to be held up due to slow progress at WVU.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The participation of ORNL and ANL, along with Gamma, Converge and OEM Navistar and along with consulting supporting from Aramco and National Research Council-Canada (NRC-Canada), is a good project team with a breadth and depth of capabilities along with WVU to make this project happen. They need to cut through the red tape and get started.

Reviewer 2

The project has all the right partners to accomplish the project but not clear what each partner has contributed to date. Again, with the project not officially signed by WVU, it is hard to perform much work.

Reviewer 3

The reviewer thinks this is a strong team leveraging unique capabilities and expertise of the team members composed of industry (Gamma Technologies, Navistar who is providing the engine, and Aramco), a national laboratory (ORNL) and others—NRC-Canada. Specific contributions are noted.

It is very early in the project at this time for review, in terms of the reviewer being able to speak to the partner participation—the links between partners to note how collaborations will work was not clear.

Reviewer 4

Having the software providers and the national laboratories makes a strong team. The reviewer would like to understand better the OEM's role. The reviewer would like to see the OEM's comments/expectations on workflow (time and effort), and model predictive accuracy/run time. These will be key if this project is to have a real impact on the product/the market. What are the roles of Aramco and NRC-Canada?

*Question 4: **Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?***

Reviewer 1

The project has a good end goal and the approach is straight forward. The reviewer would like to see more details on how to accomplish the goals.

Reviewer 2

The future work bullet points do represent the work required to complete the project to meet the defined goals. Details on the future work are lacking in the short presentation - model validation for low exhaust temperature and multi-injections were noted as the biggest challenges during the question and answer (Q&A) portion.

Reviewer 3

The basic plan elements are there, for development of a steady state model. It is unclear how / when vehicle level-transients will be handled - from both an experimental data gathering and a model calibration / verification perspective. On-road vehicle data will be great to have, but simple transients on engine dyno are likely very helpful as well - and not clearly shown. Also, what is meant by "Diesel engine optimization"? Is this hardware or calibration/controls?

Reviewer 4

A detailed workplan is needed. The overall scope is clear but a detailed step-by-step plan is needed, especially how the modelers will interface with testing.

*Question 5: **Relevance: Does the project support the overall VTO subprogram objectives?***

Reviewer 1

OEMs today are performing quite a bit of internal engine and aftertreatment models. Typically, they will run the CFD combustion model to obtain the emissions and exhaust temperatures and then use that as an input into the GT-Power aftertreatment model. This project would streamline the process and ideally allow the full simulation to be run in GT-Power. This would make it easier for the OEMs, but the reviewer is not sure it will improve the current results. It would reduce the compilation time and overall lead to more efficient aftertreatment, which should lead to reduced fuel consumption.

Reviewer 2

The project supports the subprogram objectives of reducing NO_x emissions and aiming to optimize HD diesel engine and aftertreatment systems for overall reductions in CO_2 emissions.

Reviewer 3

The work is relevant. Having accurate tools for emissions performance and system optimization are needed.

Reviewer 4

This is a fundamentally valuable workstream. Correlated full system models are needed to shorten development times and optimize complex systems. The work steps are clear and well understood.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

For what is proposed, the current resources should be sufficient to complete the project. There is some engine testing, which is expensive, but the rest is modeling and it appears there are sufficient funds to complete the modeling.

Reviewer 2

Resources seem sufficient for the project to achieve the stated milestones.

Reviewer 3

The reviewer would not increase the budget beyond what has already been allocated.

Reviewer 4

The reviewer thinks it is difficult to comment on if the resources are sufficient, because there were not many details given on the engine testing.

Presentation Number: ace173
Presentation Title: Comprehensive Integrated Simulation Methodology for Enabling Near-Zero Emission Heavy-Duty Vehicles
Principal Investigator: Andrea Strzelec, University of Wisconsin-Madison

Presenter

Andrea Strzelec, University of Wisconsin-Madison

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

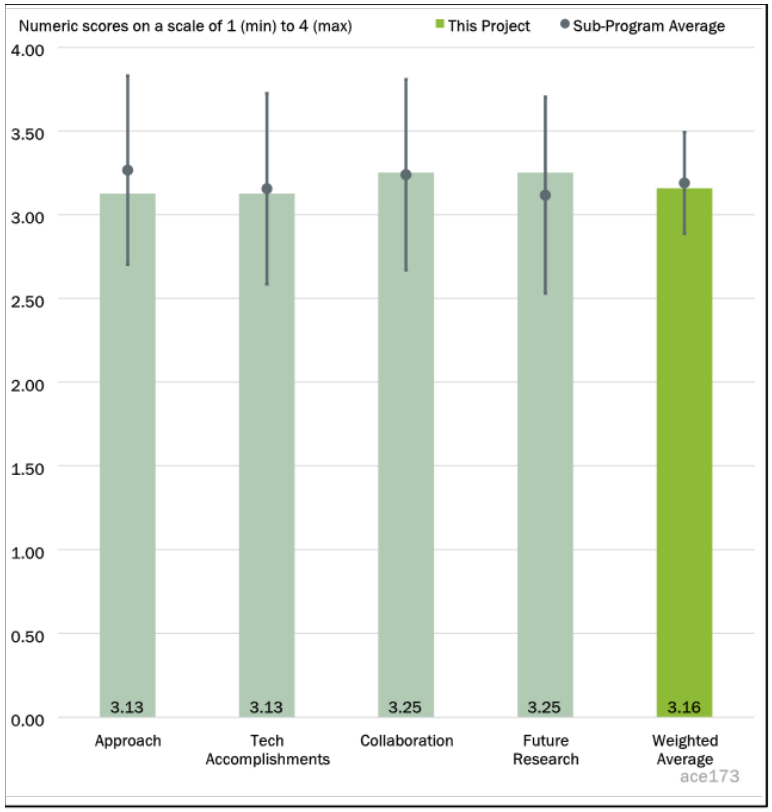

Figure 1-25 - Presentation Number: ace173 Presentation Title: Comprehensive Integrated Simulation Methodology for Enabling Near-Zero Emission Heavy-Duty Vehicles Principal Investigator: Andrea Strzelec, University of Wisconsin-Madison

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The barrier stated is that there is a lack of development models and simulation tools to predict engine and aftertreatment performance. There are some models in GT-Power but this research develops additional models for aftertreatment aging, advanced catalysts, and SCR spray breakup. Results will be used to improve the existing models and add the models that are currently not available.

Reviewer 2

It is a well-designed project to develop and validate an integrated reduced-dimensional engine, emissions, and aftertreatment system model capable of optimizing controls, thermal management, and insulation strategies while improving component conversion efficiencies to enable near-zero emissions and virtual real driving emissions. The timeline is reasonably planned.

Reviewer 3

This reviewer was pleased to see some description of the engine control variables to be explored (e.g., injection timing and EGR). The reviewer would like to see more description regarding what transient data are being generated to support Milestone "Y1-2 -…and other transient variables in a compression ignition (CI) engine". Or will the model only be validated over steady state conditions? The reviewer hopes some level of transient operation is accounted for.

Reviewer 4

The project is reasonably planned and technical barriers are well addressed, especially in terms of the development of computational tools.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The project was initiated in fiscal year 2022 and the first two milestones have been completed. These include, first, the AT system model was calibrated under baseline data conditions. The second milestone improved the prediction emission quantities and other transient variables in the diesel engine. Progress seems satisfactory for the timeframe.

Reviewer 2

The project just started several months ago. The team calibrated the baseline AT system model and baseline combustion model. Other planned researches are on schedule.

Reviewer 3

Two baseline models were listed as complete, which is good. It would be even better to show some detailed proof about how well a given task was completed.

Reviewer 4

The project is on track based on the presented slides. It would have been useful to show some results from the Y1-2 milestone on Baseline Combustion model validation.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The project has the right partners for completing the project—Gamma Technologies for model assistance, ORNL for engine testing, FEV for engine testing and model development, Isuzu an OEM engine partner, Umicore for advanced aftertreatment, and Marathon for current and future fuel requirements. The project is in the early stages so it is not certain what each partner has contributed so far.

Reviewer 2

The project team includes a national laboratory, a university, an aftertreatment supplier, an energy company, an OEM, and a consulting company. Partners are full participants and well-coordinated.

Reviewer 3

There is a good list of capable partners, with a clear split of responsibilities.

Reviewer 4

The reviewer thinks this is a strong team of collaborators with clear roles and responsibilities defined. This is a good mix of university, national laboratory, and industry participation.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer believes the project is very well laid out and has sufficient details to be carried out. The reviewer likes the fact that the plan includes revising the SCR aging model and integrating the SCR model into the GT-Suite. Another positive contribution is the prediction of the NH_3 and NO_x distribution maps at the catalyst inlet plane, and urea water spray mass histories. All the models (DOC, DPF, and SCR) will be integrated into GT-Suite. This would be beneficial to the engine OEMs and will lead to improved aftertreatment systems and improved fuel economy.

Reviewer 2

The proposed future researches are well planned and likely to achieve their targets.

Reviewer 3

The reviewer would like to see goals added to describe anticipated/expected model accuracy and run time. For model accuracy, the reviewer would like to see how it will be assessed—to be sure experimental data it is being compared to is different than that used to develop the model. Documentation of work flow, and effort, would be helpful as well.

Reviewer 4

Volume of fluid simulation outcomes may be heavily dependent on the internal of the injector flow. Developing ROM is a good idea, however, the team needs to ensure that the data used for developing such data driven models are reasonably validated and include enough upstream information.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The project targets reducing the time to develop an aftertreatment system, improving the aftertreatment system in terms of emissions and exhaust back pressure which will lead to lower overall fuel consumption, and addressing the VTO objectives.

Reviewer 2

The objective of the project is to develop an integrated simulation platform that can be used to design exhaust system architectures and control strategies that will meet future $ULNO_x$ emissions standards over the full useful life of an HD vehicle. It supports the overall VTO subprogram objectives.

Reviewer 3

Accurate models that operate on an engineering timescale are needed to meet future emissions regulations.

Reviewer 4

Yes, the project supports the overall VTO subprogram objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

Resources seem appropriate and they have the right partners to be successful.

Reviewer 2

The team has sufficient resources for this project and is likely to achieve the stated milestones in a timely fashion.

Reviewer 3

Resources are sufficient for the planned work.

Reviewer 4

The resources seem to be sufficient, although the budget table needs to be updated to correctly reflect the cost-share amounts.

Presentation Number: ace175
Presentation Title: Co-optimization of fuel physical/chemical properties and combustion system for mixing controlled compression ignition (MCCI) in a medium-duty engine
Principal Investigator: Flavio Chuahy, Oak Ridge National Laboratory

Presenter

Flavio Chuahy, ORNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

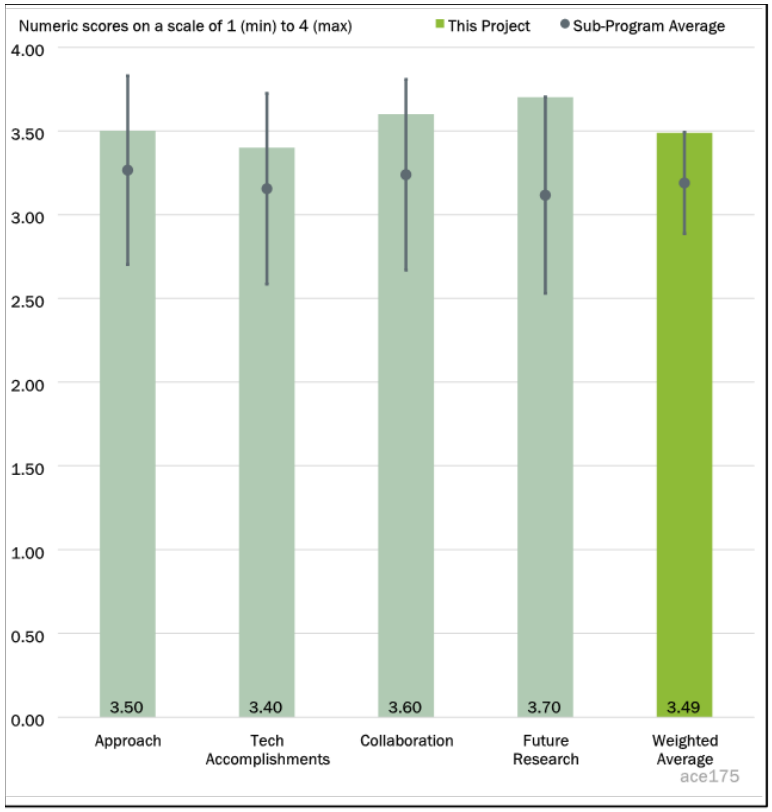

Figure 1-26 - Presentation Number: ace175 Presentation Title: Co-optimization of fuel physical/chemical properties and combustion system for mixing controlled compression ignition (MCCI) in a medium-duty engine Principal Investigator: Flavio Chuahy, Oak Ridge National Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The work is the extension of the Co-Optima project and the SuperTruck II program. The idea is that better fuels will lead to better engines. A good portion of the background work has already been completed and the project will use extensive knowledge from Cummins engineers and their modeling expertise.

The program is only 5% complete but there is a good plan in place.

Reviewer 2

The project uses well-defined and validated simulation work to explore whether there may be opportunities to optimize a medium-duty (MD) diesel engine to operate on hydrotreated vegetable oil (HVO) fuel. HVO fuel will be a major portion of the MD decarbonization effort, so rational efforts to provide improvement to engine performance and emissions on this fuel will be most welcome.

However, the issue with HVO is generally not its suitability but its availability. It is not clear exactly what this project will uncover about HVO that will enhance its use in MD/HD engines. Were other fuel choices considered?

Reviewer 3

This project uses the combination of physical geometry adaptations in the piston bowl and injector along with injection strategy and fuel chemistry to improve engine efficiency and therefore reduce CO_2 emissions. The approach is well-designed to address the technical barriers using the fully coupled MD engine-fuel platform.

Reviewer 4

This being a simulation-only project and 18-month duration is very reasonably planned. The approach to setting up a CFD optimization process with geometric and operation condition variation is very good, and would allow for transfer to the partners for extended optimization at other conditions or use cases. Additionally, the use of past CFD model setups, expertise in the optimization and ML area from Lawrence Berkeley National Laboratory (LBNL), and OEM input from Cummins, is excellent. There was not enough time to go into the fuel property specification detail, but the reviewer does have a question as to how the HVO fuel properties will be constrained to what can actually be made or tailored within typical HVO production. Will you independently vary HVO physical and chemical properties to seek a unique optimum and then go back after and constrain, or will you constrain the properties initially in the upfront definition prior to CFD simulation?

Reviewer 5

HVO diesel is widely available in states like California. The use of HVO fuel does show lower NO_x and soot, and marginal reductions in CO_2 with no specific HVO calibrations. Fuel system optimization can definitely improve these benefits; however, the approach does not explain the interaction of other engine parameters such as EGR with the fuel system optimization. Does the ML-based optimization consider the influence of EGR?

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The project is 5% complete and the first milestone for defining the fuel properties, fuel system, and piston geometry ranges has been completed. It appears that Cummins will provide quite a bit of direction on the modeling which should enable sufficient progress on all the milestones.

Reviewer 2

This project is just getting started—5% completion for a less-than-three-month activity. Project progress is difficult to evaluate but the project plan and the partners involved have shown to be able to accomplish projects on-time in the past. At the moment, this is a difficult criterion to evaluate.

Reviewer 3

The project has just been approved on March 29th, 2022 so there has been very little time for technical progress. This being said, there are a clear approach and a clear objective laid out with reasonable deliverables and resources. It was a bit unclear as to what the soot modeling approach was going to be within the CFD simulations other than looking at PAH. The reviewer suggests to clearly define this soot work (reduced order, simple Hiroyasu-Nagle and Strickland-Constable), pre-tabulated, commercially available particulate mimic / particulate size mimic models in Converge, etc.). The soot prediction and optimization surrounding it should be a very important aspect of the mixing controlled compression ignition (MCCI) optimization with a HVO that is more paraffinic and with less sooting tendency.

A final comment would be to include some thinking toward how the variation of the physical fuel properties may impact the internal flow of the fuel injection (cavitation potential increasing/decreasing), and therefore some potential changes in the injection rate shape.

Reviewer 4

Considering that the program was only approved at the end of March 2022, it is quite miraculous that the team has made any progress to date. This shows the benefit of the experienced team undertaking the work.

Reviewer 5

The project team is on schedule with their milestones, with completion of preliminary tasks associated with the definition of fuel property, fuel system, and piston geometry.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The collaboration between ORNL, Cummins, and LBNL is outstanding for a small project of this size and nature.

Reviewer 2

The collaborations in this project between an OEM and a national laboratory are outstanding. The addition of LBNL for the optimization algorithm is an excellent addition to the team. An addition of a HVO fuel supplier would be beneficial to the project.

Reviewer 3

Cummins appears to be providing significant input to the project and will help with the modeling optimization.

Reviewer 4

Because this is a CRADA, there are not many partners involved. Considering the modest budget, not many partners could be leveraged anyway. Cummins is certainly an excellent partner to have for work of this type. LBNL is also an excellent informal partner for the ML algorithm portion. However, there are no other participants or partners, whether university or otherwise. It would be helpful to have seen some university participation.

Reviewer 5

There is excellent coordination with the CRADA partner and good use of LBNL as an informal collaborator. The reviewer would have liked to see a university included to some extent.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

Future milestones are well laid out and the schedule is quite aggressive but should be achievable.

Reviewer 2

The project has clearly defined goals and the strategy is very sound and appropriate. The simulations will explore the fuel physical and chemical property space, along with engine and injector geometry - to search for the optimization potential in a low carbon, commercially available fuel. The use of ML to speed up the algorithms and solution approaches, compared to genetic algorithm, is probably the most technically interesting portion of this project.

Reviewer 3

The project has just started and, since it was awarded, it was clearly deemed to be worthy of funding in a time where ICE R&D is pressured and lowered in priority.

Reviewer 4

Proposed future work is clearly defined for the remainder of the project—it looks like an aggressive timeline.

Reviewer 5

It is unclear about the future work-related optimization for conventional 45 cetane number diesel. Optimization and calibration of engine parameters for conventional diesel should be a task that has been widely performed by Cummins over the past decade to meet stringent NO_x and GHG regulations. How will this effort be different?

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The project is investigating improving combustion efficiency by identifying fuel properties to improve the combustion and increase engine efficiency. Another objective is to evaluate HVO which is a net low-carbon fuel. Both objectives are in line with VTO objectives.

Reviewer 2

This project is very relevant to help move the industry and ICE applications toward lower carbon sustainable fuels, such as HVO.

Reviewer 3

The reviewer said this project directly supports VTO objectives in reducing the carbon footprint for engines and potentially increasing efficiency. However, it would have been helpful to see more detail on how this project will enhance HVO use, when it is already well-known that HVO is an excellent drop-in fuel for diesel. It is unclear what additional fuel/combustion benefit will be gained in this project.

Reviewer 4

Optimization of engine fueling parameters for use of HVO diesel can help reduce the dependency on fossil fuel-based diesel.

Reviewer 5

Question 6: ***This program supports the VTO subprogram objectives and keeps critical research on engines and fuels moving in a positive direction.*** ***Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?***

Reviewer 1

They are insufficient—this critical research area is being woefully under-funded.

Reviewer 2

The resources seem sufficient for this simulation-only project and given ORNL's high-performance computing capability this reviewer had concerns on the ability to execute this project. The only lack of resources is one due to a lack of scope on the validation of the optimization. The reviewer encouraged additional funding and scope to test the produced MCCI combustion system and go back to validate the CFD predictions.

Reviewer 3

Resources are sufficient, based on the prior work that has already developed the baseline models and that are only being extended to the HVO fuel and extending the diesel fuel properties. Again, the support from Cummins will definitely improve the probable success of the project.

Reviewer 4

For a simulation project, the resources allocated should be sufficient to support progress toward the goals.

Reviewer 5

The resources provided by Cummins and LBNL are sufficient to complete the milestones of this project.

Presentation Number: ace177
Presentation Title: Independent Fuel Property Effects of Fuel Volatility on Low Temperature Heat Release and Fuel Autoignition
Principal Investigator: Sibendu Som, Argonne National Laboratory, and Jim Szybist, Oak Ridge National Laboratory

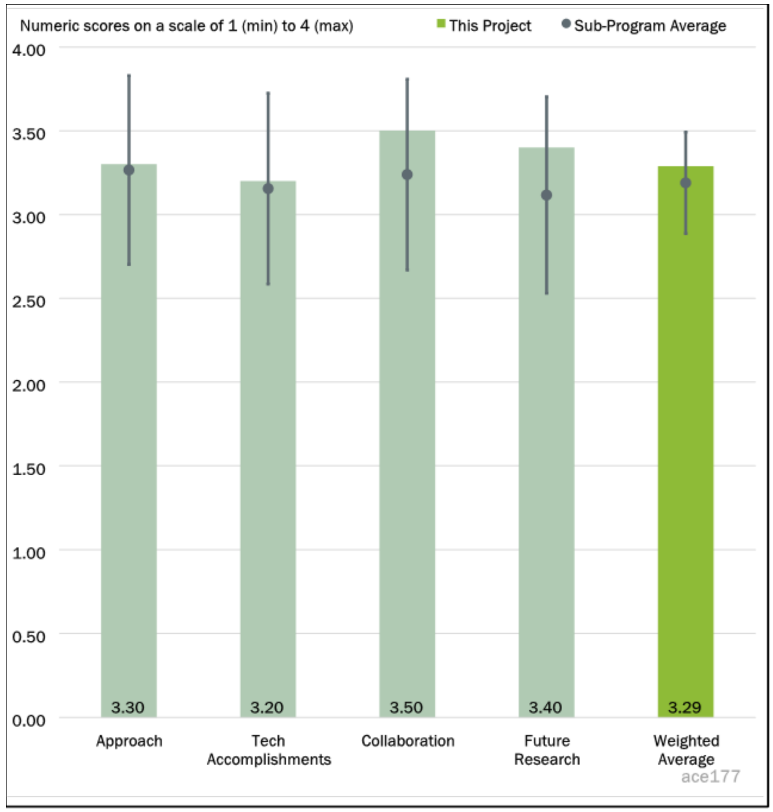

Figure 1-27 - Presentation Number: ace177 Presentation Title: Independent Fuel Property Effects of Fuel Volatility on Low Temperature Heat Release and Fuel Autoignition Principal Investigator: Sibendu Som, Argonne National Laboratory, and Jim Szybist, Oak Ridge National Laboratory

Presenter

Sibendu Som, ANL, and Jim Szybist, ORNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This is a new project and is just getting started. The approach follows on learnings from the Co-Optima program and seeks to explain an interesting subtlety of lower in-cylinder low temperature heat release (LTHR) behavior of fuels with the same research octane number (RON) and motor octane number (MON) but higher volatility. Using already established databases on the chemical composition differences during vaporization resulting from the azeotropic behavior of the higher volatility fuels, both experiments and simulations will be conducted for a matrix of fuels with known composition and volatility in an attempt to determine the reason of the observed differences in LTHR.

Reviewer 2

This work is well-designed to understand fuel effects on spark ignition (SI) combustion for boosted engines. A possible weakness, based upon the presentation material and questioning of the presenter, was that the work was claimed to be relevant to different combustion strategies / modes, but the presenter and the presentation material did not really expand well upon how exactly this would occur or be deduced. To say this differently, to ensure that the work is relevant to a wide range of combustion strategies and modes, it is critical that the work span a range of pressure, temperature, and dilution conditions, with both fuel lean and residual gases used to achieve dilution -- and then the method for connecting the results to those combustion strategies and modes should be clearly explained. For example, how will the results be applicable to highly dilute SI engines, high expansion ratio SI engines, partially premixed compression ignition engines, etc.? Given previous work by the team members, there is little doubt that they can do this, but it just was not apparent from the material presented.

Additionally, while it clearly was well thought out, a bit more explanation behind the logic used for the fuel matrix would be helpful. (Why does it seem that the primary interaction that is being examined is aromatics with other compounds?)

Finally, a minor comment: while it is clear that the authors understand the phenomenon they are attempting to describe, this reviewer is not sure that the term azeotropic is being used correctly. (It has a very specific meaning which is not what the authors are intending to describe.)

Reviewer 3

The technical approach is well defined. It leverages the expertise of the project participants—Shell for fuel formulation, ORNL for combustion testing, and ANL for combustion simulations.

While the approach to investigate the impact of fuel volatility (vapor pressure) on LTHR and autoignition is well defined, it is not clear how the knowledge gained from this study will be applied. Perhaps the industry partner can help lay out the vision for utilizing the insights gained from this study to benefit boosted SI engines and/or HD advanced compression ignition (ACI) engines.

Reviewer 4

The project has a very specific goal and approach to achieve it. This is regarded as an effort for verification and validation of already developed capabilities and expertise for fuel modeling and in-cylinder combustion simulation with it. The reviewer wonders if any potential risk (e.g., model not reproducing the test results well) has been considered.

Reviewer 5

This study concerns developing an understanding of fuel property effects on engine performance. The project seeks to understand certain issues related to fuel volatility such as its effect on heat release rate and preferential vaporization associated with the highly multicomponent fuel systems. Here, the project incorporates several mixture blends (apparently surrogates) for 10% ethanol, 90% gasoline blend (E10).

The approach taken is to combine engine testing with detailed numerical modeling using fuels provided by Shell. This coordination is good. Somewhat lacking is a clear definition of ‘preferential vaporization’ (see below) that could guide the work to enable the PIs to work to monitoring and simulating.

It is unclear also if the engine tests are too system-level to resolve the influence of preferential vaporization (however the PIs define this term) on engine performance. It might be considered to include a more basic/simpler experimental configuration to first establish that preferential vaporization (according to the PIs’ definition) does occur for the fuel blends examined, and then to move to engine testing to determine if it is revealed in the data and its possible connection to LTHR.

The reviewer notes that in the ANL simulations please note the combustion kinetic mechanism being used and how it was validated. Also, since the Shell blends are comprised of several components, a discussion of the property database incorporated in the simulations would be appropriate.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

With the CRADA having been finalized in April 2022, the project is still in the initial stages. Consequently, the PIs have had a very limited opportunity to complete technical tasks thus far. As per the project timeline, the industry partner has completed designing the fuel matrix and fuel blending is in progress.

The project participants have an impressive track record of delivering high-quality data and analyses as evident from their prior contributions to the Co-Optima program. It is expected the PIs will leverage their expertise to further highlight the impact of fuel properties on enhancing combustion in modern engines. The results from this study and subsequent technical reviews are eagerly awaited.

Reviewer 2

This work is just starting, so this is difficult to evaluate.

Reviewer 3

The project is just starting so there are minimal technical accomplishments on which to comment. The program appears to be well thought out with cooperation between relevant stakeholders.

Reviewer 4

Because the project is fairly new, there is not too much of accomplishment to evaluate. The presenter mentioned that the number of fuels to be tested (and shown in the presentation) has been pushed back to Shell, due to too many variants. Is it because of the resource availability?

Reviewer 5

The outcome of this project is ostensibly to determine if preferential vaporization is responsible for suppression of LTHR in high volatility fuels. This is an important issue. However, from the information provided in the presentation, it was not clear precisely how the team defines this concept of ‘preferential vaporization’. What is the specific fuel property that would promote it? Is it fuel component boiling points? Heats of vaporization? And how is preferential vaporization revealed in the experimental results? That is, what specific metric in the engine test data would provide the evidence for its existence. It may be possible that the experimental output does not strongly suggest that one component dominates evaporation initially, then another and so forth. At the least, a clear definition of what is meant by ‘preferential vaporization’ should be offered and a discussion of how it is to be monitored provided.

The numerical modeling effort could provide insights into performance metrics that are inaccessible in the experiments. An example would be the internal distribution and evolution of mixture species in the liquid fuel as the components evaporate and ignite. Can the ANL modeling effort provide such a level of detail?

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This is a good collaboration between two national laboratories and a fuels provider that leverages the expertise of each.

Reviewer 2

The reviewer noted well-aligned coordination.

Reviewer 3

Have the researchers considered interfacing with the United States Council for Automotive Research (USCAR) for comments on their approach? The program addresses fuels for spark ignition engines, so if successful these lower carbon fuels would be used mostly in the light duty legacy fleet. The auto industry might have good insight into whether technical challenges would be experienced in fueling legacy fleets with fuels of different volatility: once the reason for the sublet behavior is understood. Interaction with USCAR could inform the researchers if the changes in the fuels' volatility would be tolerable in the range of vehicles in the legacy fleet.

Reviewer 4

While the project is still in the early stages, in part due to the experience of the PIs and the industry partner having collaborated on studies in the past, the project appears to be off to a smooth start.

It is recognized that the objective of this project is to investigate the impact of vapor pressure on LTHR/autoignition and not to develop a production ready application/control strategy. However, the PIs and the industry partner are encouraged to discuss potential applications for implementing the insights gained from this study.

Reviewer 5

The work of the four groups appears to be well-coordinated as it combines numerical modeling (ANL) with engine testing (ORNL) and fuel blend preparation (Shell). The concern is, as noted previously, the extent to which the experiments can provide information to reveal preferential vaporization, or what one looks for in the simulation or experiments to evidence it.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The plan is good: some of the items mentioned above should be addressed in the plan, but overall the plan is good.

Reviewer 2

It is understood that as the project evolves, the future research needs may evolve as well. At present, the PIs have a well-defined plan for achieving the goals of the project with the roles and responsibilities of different teams clearly identified.

Reviewer 3

Again, there is a clear plan with milestones.

Reviewer 4

The planned activities seem to be more over-arching than detailed and specific, for example 'simulation of ORNL experimental measurements' (i.e., what specific variables will be simulated, what will be measured, what is the expected accuracy of the variables to be measured and under what operating conditions, and what is the strategy for closing the gap between simulation and engine testing if the agreement is not good?).

Reviewer 5

The experimental and computational program is well laid out. Do the researchers anticipate challenges in developing representative surrogate fuel compositions to accurately capture the volatility variations among the test fuels?

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This project is aligned with DOE's goal of improving engine efficiency and identifying cost-effective high-performance fuels.

Reviewer 2

The project is aligned with the objectives to obtain better knowledge and to improve tools for higher efficiency engines to help decarbonization.

Reviewer 3

The project is relevant to DOE's interest from a broad perspective.

Reviewer 4

This program is very relevant to increasing efficiency, and so it supports the VTO objectives.

Reviewer 5

Because of the time required for the transition to an EV dominated mobility market, there will be combustion engines using liquid fuels for many decades to come. Reducing the GHG emissions of these vehicles via fuel modification will make a significant, integrated impact in GHG footprint reduction as we move toward the ultimate sustainable mobility system.

Question 6: ***Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?***

Reviewer 1

The team is highly capable and the resources are sufficient for project success.

Reviewer 2

The researchers made no comment about the adequacy of the resources. So, this reviewer assumes they are adequate.

Reviewer 3

The funding allocated for this project appears to be sufficient to complete the proposed work.

Reviewer 4

The reviewer thinks the project has sufficient resource allocation.

Reviewer 5

The resources seem adequate, though without more details of how the funds are spent it is not possible to adequately score this category. An ultimate judgement of costs comes from a cost/benefit analysis based on DOE's investment relative to the perceived value of what the PIs are pursuing.

Presentation Number: ace178
Presentation Title: Development Of Advanced Combustion Strategies for Direct Injection Heavy Duty Liquefied Petroleum Gas (LPG) Engines
Principal Investigator: Dan Olsen, Colorado State University

Presenter

Dan Olsen, Colorado State University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

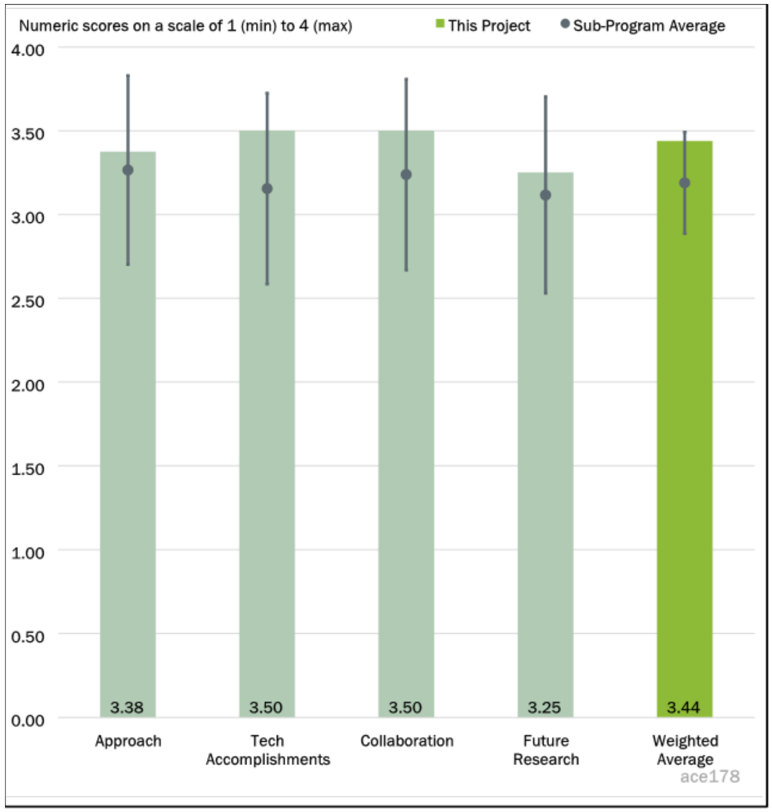

Figure 1-28 - Presentation Number: ace178 Presentation Title: Development Of Advanced Combustion Strategies for Direct Injection Heavy Duty Liquefied Petroleum Gas (LPG) Engines Principal Investigator: Dan Olsen, Colorado State University

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The objective of the project is to increase the peak efficiency of a 15-Liter liquified petroleum gas (LPG) engine to near-diesel efficiency. The project covers a fundamental LPG chemical kinetic study, spray research, and engine research. The timeline is reasonably planned.

Reviewer 2

The PIs understand the issues with operating a two-phase LPG engine and have tailored the objectives and plan to address them. The technical approach is impressive between the CFD modelling and the Schlieren imaging of the RCM combustion to determine the ignition effects of two-phase LPG sprays. Flame speed tracks extremely well between experiment and the model. The Schlieren images do show that the flame is not laminar. Modelling efforts to show fuel spray and knock are successful.

Did the PIs force the ignition with laser spark on the ignition delay timing plots? If so, does that explain some of the differences between the non-pure propane results?

Reviewer 3

This project has used chemical mechanism development, CFD model development, along with experimental studies (RCM, spray imaging, Cooperative Fuel Research (CFR) engine) to provide necessary fundamental understanding of LPG combustion and fuel spray for LPG engines to provide a pathway towards reaching 44% BTE. The timeline is properly planned.

Reviewer 4

The biggest technical barrier is the direct liquid injection and the team has been making efforts in achieving it. The issue is translating it into a system for a vehicle. In other words, for stationary engines or engines in test-cells, solutions with chillers will work. Translating this to real-world on-road applications will be a challenge. Nonetheless, a high flow injector, an electric lift pump, and a high-pressure pump are the way to go to enable direct injection (DI) liquid injection for propane.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The development of a high flow injection system for LPG is not an easy task. The researchers have done this without lubricity additives which is also impressive.

Reviewer 2

Overall, good progress has been made.

Some experimental investigations have been finished, including LPG ignition delay, flame propagation, spray visualization, and modeling. Good progress has been made on fuel injection visualization, development of the spray model with experimental validation, and CFR engine testing.

For the RCM ignition delay study, heat loss occurs for every experiment, and this needs to be corrected for in the model validation. The flame propagation in an RCM is not a laminar flame, thus the project needs to be careful when the data is used for flame speed validation.

Reviewer 3

The project enhanced the chemical kinetic mechanism for LPG combustion and the results for predicting ignition delay are experimentally validated against RCM ignition delay measurements. Another important accomplishment is the accurate modeling of two-phase LPG flow for high pressure direct injection, showing validations with varying reformed-exhaust gas recirculation % mass substitution conditions. A further important achievement is CFD model development and validation for combustion performance analysis and predicting heat release rate.

Reviewer 4

The team has performed very well and has accomplished the negotiated milestones so far. CFD analysis, chemistry mechanism development, and CFR engine testing have been completed. Port fuel injection testing is to commence and finally the DI testing will take place.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The collaboration between the industry partners, national laboratory, and Colorado State University is impressive. The quality of results from this project would not be as high if there was not such a high degree of collaboration.

Reviewer 2

Overall, the team did a good job in collaboration within the project team. For example, spray imaging was used to validate the spray model. Improvement can be made by better coordinating CFD and engine design. Also, it could be better to run the CFR engine at a compression ratio (CR) similar to the Cummins X15 single-cylinder engine (SCE).

Reviewer 3

The results presented show strong collaborative efforts among the industry partner (Cummins), the national laboratory (ANL), and academia (Colorado State University).

Reviewer 4

Excellent collaboration and this work is timely as Cummins is commercializing the propane B6.7 (6.7-Liter) engine.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

Port injection and then DI is the way to go to reduce technical barriers. If success is found in port injection, this could also lead to a commercial solution.

Reviewer 2

Future research focuses on combustion strategy development, engine testing, and system optimization. What is the key contribution of the CFR engine experiments? Why not develop an advanced combustion engine using the X15 Cummins SCE directly? For Task 7 on System Optimization for Near-Diesel Efficiency on X15 SCE, it is not clear what will be optimized.

Reviewer 3

This project has a clear proposed pathway for future research to reach 44% BTE at peak torque.

Reviewer 4

A strong plan for injector modeling and hardware integration is considered. But the development of the combustion recipe to achieve near-diesel efficiency needs a more detailed plan.

Question 5: Relevance: Does the project support the overall VTO subprogram objectives?

Reviewer 1

With the increased usage of HVO for renewable diesel and sustainable aviation fuel, there is an ever-increasing supply of renewable propane which is a byproduct of the process. This propane has a net zero carbon intensity (CI) score because the CI of the propane is applied to the renewable diesel. This allows for the usage of a net-zero carbon fuel in transportation. Once regulation catches up to the fuel and re-apportions the CI scores, it will still be a low-carbon low-emissions fuel. This is very relevant to current HD needs.

Reviewer 2

The objective of the project is to increase the peak efficiency of a 15-liter LPG engine to near-diesel efficiency. It supports the overall VTO subprogram objectives.

Reviewer 3

The project clearly supports VTO - Advanced Engine and Fuel Technologies objectives by increasing the peak torque efficiency to near-diesel brake thermal efficiency (44%); thus "generating the knowledge and insight necessary for industry to develop the next generation of engines for light-and heavy-duty vehicles."

Reviewer 4

Project is relevant to DOE goals for improving the technology and adoption of alternative fuel engines.

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

Reviewer 1

While there are sufficient funds at this time, the reviewer would recommend that the funding of the Decarbonization of Off-Road, Rail, Marine, and Aviation program (formerly Advanced Combustion Engines) be re-evaluated and possibly increased to 2022 levels. Research programs such as this are necessary for the transition to low carbon transportation.

Reviewer 2

The team has sufficient resources for this project. Key facilities, such as RCM, CFR, and high-speed Schlieren, were used for kinetic, spray visualization, and engine performance research. Cummins supports the design, fabrication, and delivery of the X15 SCE head, installation and commissioning. ANL supports the CFD modeling.

Reviewer 3

Adequate resources are available. Cummins' continuous involvement for different stages of the project for design, fabrication, and delivery of the X15 SCE LPG-DI head is very important.

Reviewer 4

Resources are sufficient to accomplish the remaining work elements.

Presentation Number: ace179
Presentation Title: Propane longstroke engine R&D
Principal Investigator: Derek Splitter, Oak Ridge National Laboratory

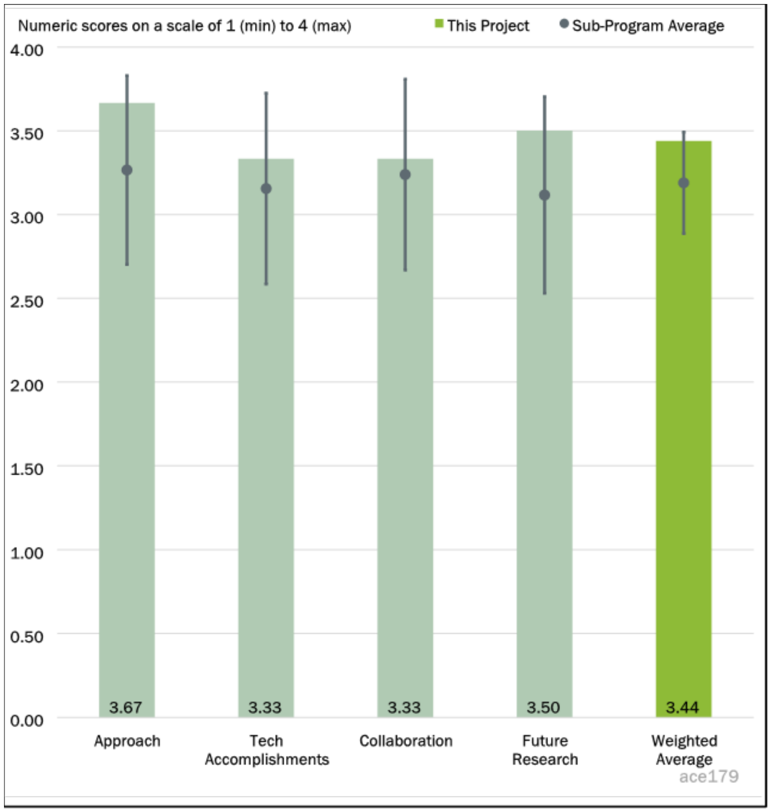

Figure 1-29 - Presentation Number: ace179 Presentation Title: Propane longstroke engine R&D Principal Investigator: Derek Splitter, Oak Ridge National Laboratory

Presenter

Derek Splitter, ORNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The project is very well designed and includes fundamental combustion kinetics, CFD analysis, SCE testing with the assistance of CFD-guided design, system-level simulation, and total cost of ownership/life cycle analysis (TCO/LCA). Overall, the timeline is reasonably planned.

Reviewer 2

The project provides a better understanding of the effectiveness of EGR to mitigate knock.

Reviewer 3

ORNL has performed a tremendous amount of work on the fundamental understanding of propane's robustness to EGR. In addition, the fundamental understanding of the ignition chemistry with the formation/dissociation of hydrogen peroxide is critical in understanding the behavior of these fuels with EGR. Currently, there are not many propane engines operating with EGR (the reviewer knows there are some from Zenith Power Products), but this project helps the propane industry in new product development. The reviewer would have liked to see the approach on direct liquid injection of propane, which was not shown at the AMR. This is one of the biggest barriers for commercialization.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The program is 30% complete to date. The delay is primarily due to the pandemic and supply chain delays, which is understandable.

The PIs did an excellent job in fundamental ignition simulation and conceptual understanding of dilution effects on flame and ignitions. Two-dimensional direct numerical simulation was used to understand the fundamentals of fuel properties enabling improved EGR tolerance. The team also made progress in developing the second-generation long-stroke engine.

Reviewer 2

The DNS results provide a fundamental understanding to explain why propane combustion is less affected with EGR changes. The Fast, Robust Engine Simulation Code (FRESCO) results provide experimentally validated CFD simulations for pressure traces.

Reviewer 3

The team was a bit behind on milestones but made up for it as acknowledged at the AMR. The project is proceeding as per plan.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The team is a good combination of a national laboratory, universities, and industry. So far, the team did a great job in coordinating tasks. For example, the chemical kinetics study supports the DNS and assists in developing sub-models for combustion system and engine design optimization.

Reviewer 2

The results presented show the collaborative efforts between team partners (e.g., Wisconsin Engine Research Consultants, Oakland University).

Reviewer 3

Katech should have a prominent role with the delivery of the DI system and this reviewer's concern is that no particular progress on Katech's development for the second-generation engine was presented at the AMR. As noted in Slide 16, "Katech–Sub recipient: Engine design integration for Gen 2 prototype" but this was not evident from the AMR presentation.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

Future work includes a Gen 2 engine installation and experiments across a wide range of conditions demonstrating efficiency achievements; closing the loop on simulation results with Gen 2 engine validation, prediction, and optimization simulation; and life cycle and efficiency analysis against a diesel baseline engine. The team is likely to achieve the originally planned targets.

Reviewer 2

The reviewer said a clear path is presented for using the Gen 2 engine, and the design activities are planned.

Reviewer 3

The reviewer commented the proposed future work is in line with the objectives of the project. With diesel-like efficiencies with EGR, the TCO and LCA will clearly outline the value proposition of SI propane engines for the medium-duty market.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This project will develop and demonstrate a propane-specific prototype single-cylinder advanced spark-ignition MD relevant engine that achieves diesel engine efficiency parity and shows pathways for dramatic engine efficiency increases. It supports the overall VTO subprogram objectives.

Reviewer 2

The project clearly supports VTO Advanced Engine and Fuel Technologies objectives.

Reviewer 3

This project advances the development and commercialization of alternatively fueled engines and is in line with DOE objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

ORNL could benefit with additional funds for a full experimental mapping of the long stroke engine. DOE should consider a total of $2 million federal investment for this project (i.e., an increase of $600,000 in funding for complete experimental evaluation).

Reviewer 2

The project was delayed by nine months due to the pandemic and supply chain issues. The reviewer is confident the team can catch up and achieve the target as planned.

Reviewer 3

Adequate resources are available and the collaboration with Stellantis would be helpful for the project support.

Presentation Number: ace182
Presentation Title: Fully Electric Powered, Hydraulic Assisted, Compact Track Loader
Principal Investigator: Perry Li, University of Minnesota

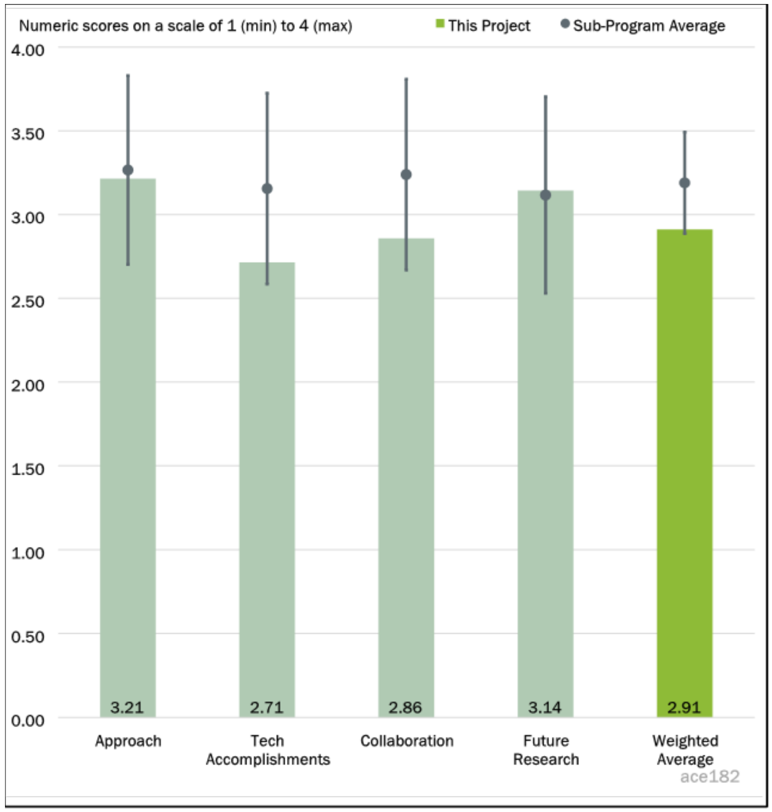

Figure 1-30 - Presentation Number: ace182 Presentation Title: Fully Electric Powered, Hydraulic Assisted, Compact Track Loader Principal Investigator: Perry Li, University of Minnesota

Presenter

Perry Li, University of Minnesota

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The approach is very innovative and the timeline is reasonably planned. It leverages the advantages of both hydraulic (power dense) and electric (efficient) systems to design a highly efficient architecture with a battery size that is more pragmatic for off-road applications than traditional fully electric powered systems that will require high power electric machines. Well done!

Reviewer 2

The concept is unique and intriguing from the perspective of maximizing efficiency. This reviewer questions if the incremental gain achieved by adding the modulating motors/pumps will be worth the additional cost compared to just a multi-rail system without the additional pumps/motors. Hopefully the project will look at not only the efficiency gains, but will also look at the incremental cost and evaluate the ROI.

Reviewer 3

The project objective is to demonstrate a fully electric powered functional compact track loader using Hybrid Hydraulic-Electric Architecture. The goal is to decrease battery power requirements by 40%, thereby reducing the carbon footprint by 80% relative to a diesel-powered track loader. This is to be accomplished by using small electric motors to drive individual pumps connected to a multi-rail system. This is a promising technology and the proposed technical approach is outstanding.

Reviewer 4

This project is brand new, but there are references to a previous project that the PI was conducting, which provides confidence in the approach and understanding. The concept is trying to utilize the "best of hydraulics and electrical components." The approach of getting the concept and simulation complete first and transitioning to an actual machine is very good. The timeline also seems reasonable.

The PI's statement that the project consumed ~$1,087,921 in fiscal year 2021 should be checked and corrected. The project did not start until February 2022.

Reviewer 5

The documented project scope and activities are well designed to target addressing the technical barriers identified. The timeline presented appears reasonable and the proposed progress of work and milestones demonstrates measured progress toward the overall project objectives.

Reviewer 6

This project does an excellent job of addressing the barriers of system efficiency, GHG emission, and the high cost of electrification by using a hybrid hydraulic-electric architecture that will maintain needed access to high power density actuation while reducing throttling losses. The project builds on results from a prior project. The project is well-designed and the timeline is well-planned.

Reviewer 7

The overall idea of using hydraulics on the propel for an electrified machine is not reasonable. The conclusion that a direct replacement of hydraulics on the rotary motion and its advantages in terms of efficiency has been well documented and researched. The timeline is very preliminary and very little details were shared; therefore, it is difficult to evaluate how reasonable it is.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The project has just recently started but appears to be off to a good start.

Reviewer 2

The project has been running since March and no progress was presented.

Reviewer 3

The project is at the initial phase but the proposed approach is fundamentally sound. The only suggestion for the project team to consider is that the proposed system architecture has three common pressure rails but they should also investigate how to optimize the number of common pressure rails since that will have significant implications on the system performance, cost and sound quality.

Reviewer 4

The progress on Slide 7 demonstrates a slow start to the project. Focus should be on team finalization and initiation of the activities identified for the current budget period as identified on Slide 7.

Reviewer 5

Not applicable as the project is at kickoff stage.

Reviewer 6

The project was just initiated so it is difficult to assess technical progress at this early stage. However, based on the results of the previous project, the team is well prepared to make progress toward the project goals.

Reviewer 7

Early to tell. Only 1% completed according to the PI. Previous work provides a good basis for this project.

Technical questions that the reviewer would like the PI to address: First, see how you are efficiently supplying multi-rails with one pump. It seems the key to the performance will be the "soft switching" valve. It will be interesting to understand the reasons for it and how to make this concept work smoothly. Was there a significant pressure ripple during the previous project study that led to a new concept? Second, define "input energy"—Is it the pump input energy of the baseline machine? Third, do you feel that the assumption that the machine spends an equal amount of energy on propulsion and the work circuit during operation is adequate? Perhaps the opportunity for efficiency improvements should be reconsidered. Recommendation: These machines perform many different tasks; the recommendation is to analyze a "composite work cycle" to understand overall energy savings. Fourth, is the engine efficiency only 25%?

*Question 3: **Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?***

Reviewer 1

The reviewer said it appears to be a strong team with diverse backgrounds.

Reviewer 2

It was not explained how the partners collaborate and whether this is done on regular basis.

Reviewer 3

There is broad based collaboration across the project team between universities, OEM, and critical component suppliers. The roles and responsibilities as well as expected contributions of all the partners are well defined.

Reviewer 4

The identified partners/collaborators on Slide 8 are appropriate with defined roles and responsibilities. The slow start to the program may demonstrate that the collaborators are not well coordinated yet. Initial meeting cadence needs to be set and the collaborators need to be directed on initial activities to start executing the work plan.

Reviewer 5

The reviewer said not applicable as the project is at kickoff stage.

Reviewer 6

There is a set of five collaborators from a combination of university, OEM, and lead suppliers which brings a good set of resources to the project. Responsibilities of each party were outlined. The frequency of collaborator meetings and interactions should be described and provided to the reviewers.

Reviewer 7

There is no real understanding of collaboration by reading the presentation. The partners look very strong and in my opinion, they are capable to deliver on the assigned roles.

Question 4: Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1

The reviewer suggests more emphasis on the cost and estimated ROI of additional hardware for the modulating pumps/motors.

Reviewer 2

The overall idea of using hydraulics on the propel for an electrified machine is not reasonable.

Reviewer 3

The project has clearly defined the relevance of the future work, which is likely to achieve its targets.

Reviewer 4

The proposed future research clearly outlines future steps (from modeling all the way to machine testing with the new concepts).

Reviewer 5

The future work defined on Slide 9 is well documented and has a clearly defined purpose. If executed, the future work defined should have a high likelihood of achieving the project objectives.

Reviewer 6

The plan to optimize the hydraulic system architecture for the demonstration rig, develop testbeds for control development, and select the soft switch valving concept for prototyping is logical and addresses the appropriate issues.

Reviewer 7

The project has just been initiated so most of the work is in the future. The purpose of the work has been defined. Based on the past history of the group, the project seems very likely to achieve its targets.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This project is very relevant. The goals are consistent with DOE objectives and if successful could lead to significant fuel savings. This reviewer appreciates that this project is exploring new concepts/architectures as opposed to just an implementation project.

Reviewer 2

If the project team is successful in delivering the proposed energy savings, the solution will address a critical need in the off-road industry and support the overall VTO initiatives to decarbonize energy intensive industries as well as enable a net-zero agricultural sector.

Reviewer 3

The approach seems relevant for electrification and hydraulic system efficiency improvements. More detail would make it easier to assess, but a high-level statement of future work is relevant and aligned with OEM trends. The concept is trying to utilize "best of hydraulics and electrical components."

Reviewer 4

The project is directly working to improve the efficiency of the hydraulic-electric system on the machine and ties directly to system-level efficiency improvements.

Reviewer 5

A hybrid blend of hydraulic and electric architectures has the potential to improve hydraulic system efficiency and extend the range of battery powered off-highway vehicles, thereby supporting the VTO objective of decreasing GHG emissions.

Reviewer 6

Yes, this project investigates the potential Hybrid Hydraulic-Electric Architecture in reducing energy and emissions using electrification of a loader. The knowledge gained from this work will be extendable to other off-road vehicles.

Reviewer 7

The topic of electrified machines and their efficiency is very relevant; however, the technologies and approach presented on this project are not relevant.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The project brings together an excellent team combined with good DOE and partner resources that should enable the achievement of the stated milestones in a timely fashion.

Reviewer 2

The project appears to be well resourced.

Reviewer 3

The resources should be sufficient for the project team to achieve the stated milestones in a timely fashion.

Reviewer 4

It seems that the project has strong players and enough engagement from the team to get things done in a timely fashion (OEM, component suppliers, and two universities with the relevant experience in controls, hydraulics, and electric components).

Reviewer 5

The reviewer said the sufficient rating is an assumption that the project collaborators are assigning the proper resources to execute their responsibilities. The current state of the project and documentation included makes a data-based assessment of resources difficult.

Reviewer 6

The budget appears to be sufficient given the project scope, effort, and deliverables.

Reviewer 7

The amount of resources that have been provided to the previous project and the currently running project are excessive relative to the outcome and non-existent demonstration on a real machine.

Presentation Number: ace183
Presentation Title: Articulated Dump Truck (ADT) Electrification - Greenhouse Gas Reductions and Commercialization of New Technology
Principal Investigator: Brij Singh, John Deere

Presenter

Brij Singh, John Deere

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

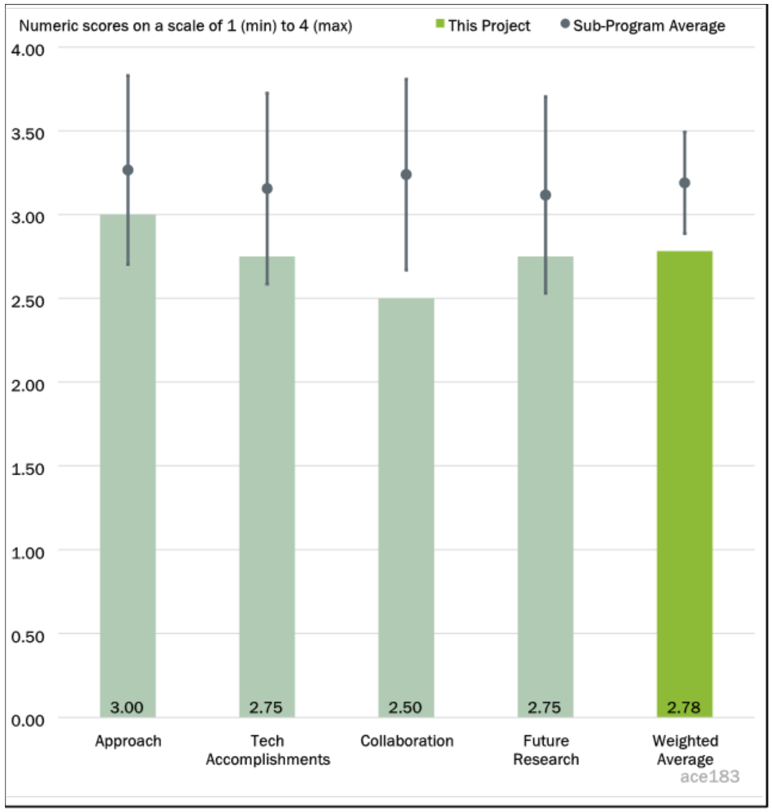

Figure 1-31 - Presentation Number: ace183 Presentation Title: Articulated Dump Truck (ADT) Electrification - Greenhouse Gas Reductions and Commercialization of New Technology Principal Investigator: Brij Singh, John Deere

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The project is fairly new but the approach presented is reasonable. The timeline is ambitious.

Reviewer 2

The approach is well balanced with its evaluation of technical and economic factors, and its comparison to an established production system.

Reviewer 3

The technical barriers are well addressed, and they are incorporated into the project goals/objectives. The principal investigator has a good grip on issues related to the dependency of the diesel-electric hybrid power train on the direct current/direct current (DC/DC) converter, soft-switch inverter and sizing of the lithium-ion (Li-ion) battery pack as well as on how the latest advances in materials science, such as silicon carbide (SiC), can improve converter and inverter components. The timeline seems reasonable but only the milestone schedule is given for year 1 of the three-year project. It would be better if the reviewer were able to see what accomplishments are planned for years 2 and 3 to gain confidence that the timeline is actually reasonable, exclusive of supply chain issues.

Diesel-electric hybrid powertrains already exist for railroad locomotives. The project should have been required to do an assessment of what technology can be transferred from existing diesel-electric hybrid powertrains and what cannot be transferred with reasons stating why in order to document lessons learned and to avoid the appearance of "re-inventing the wheel".

Reviewer 4

The reviewer identified as strengths the general approach appears sound including downsizing of the engine, adding an electric infinitely variable transmission and battery pack, and working to improve the technical performance of DC/DC converters and SiC inverter to meet project requirements. The project presents an approach to address the identified technical barriers of SiC inverters and SiC/Si DC/DC converters. Some details are provided on the technical specifics. The approach will leverage experiences from electrification of many vehicles in Deere.

The reviewer-only slides do discuss critical assumptions and issues and outline some alternatives with regards to soft-switched SiC inverters and SiC metal-oxide-semiconductor field-effect transistors (MOSFET)/Si MOSFET DC/DC converters. So, in a way, this is a targeted risk mitigation strategy. However, an overall project risk mitigation strategy has not been presented. If the identified requirements for the power electronics cannot be achieved, what is the fallback plan?

The reviewer identified as weakness as there is no mention of a preliminary cost analysis in Budget Period 1. A cost assessment appears to be put off until near the end of the project which is too late. No specific information is provided with regards to how cost reductions will be achieved to improve the odds the system will be commercially viable. For example, how can cost be captured / minimized upfront in the design process?

On the last slide for "Approach", no specific timeframes are provided for the "Fabrication, Testing, & Characterization of Components for the Diesel Electric Hybrid Powertrain" and "In-vehicle Integration of Diesel-Electric-Hybrid Powertrain and Technology Validation" tasks, including the Value Propositions. It can be surmised that these elements are proposed to be conducted late in Budget Period 2 or probably Budget Period 3. It would be beneficial if a preliminary analysis of these value propositions (i.e. fuel economy and system costs) could be conducted much earlier in the project (e.g., end of Budget Period 1). No specific milestones are provided past Budget Period 1.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

Difficult to evaluate due to the stage of the project.

Reviewer 2

The project was just initiated so there are no technical accomplishments to be manifested.

Reviewer 3

Given the project has not contractually started, technical progress should not be rated at this time. John Deere seems to have a clear understanding of their plan and ready to execute when the contract is signed.

Reviewer 4

This is a new project start and, as such, no specific technical accomplishments have been achieved. Some business-related activities such as brainstorming meetings and signings of confidentiality agreements have been conducted.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

Project roles and responsibilities appear to be well defined. This should result in excellent collaboration and coordination.

Reviewer 2

Difficult to evaluate due to the stage of the project. However, neither the presenter nor the presentation included any of the work breakdown and the responsibilities of each partner.

Reviewer 3

The partners include four internal divisions within John Deere and two academic institutions (i.e., North Carolina State University and University of Arkansas), so collaboration and coordination are extremely limited. It would be much better if a manufacturer or supplier of inverters and converters could be included on the project team so that the pragmatic expertise/experience of an important supplier could be taken into account.

Reviewer 4

As a new start, there is not much information to go on. However, the project appears to have initially established solid collaborations with two universities (North Carolina State University and University of Arkansas) for power electronics R&D. Given the criticality of power electronics advances to the success of the project, to mitigate risk it would be beneficial to explore further collaborations in this space including with other industrial firms.

It may also be beneficial to explore collaboration(s) with battery manufacturers, especially as the battery management system of the Li-ion battery pack has been identified as a critical issue.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

Yes, the work has been clearly defined. Roles and responsibilities are clear and appropriate metrics are being used. Probability of project success is high.

Reviewer 2

All of the project is future work at this point.

Reviewer 3

This reviewer's evaluation of proposed future research is based on only the milestone schedule presented for year 1 of the project. As aforementioned, it would be better if the milestone schedules for years 2 and 3 were also available.

Reviewer 4

Not applicable as this is a new project. Discussion of upcoming work is discussed under Question 1 and 2 on "Approach to Performing the Work".

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

As stated, the proposed diesel-electric-hybrid powertrain will result in over 20% fuel savings in the pilot electric Articulated Dump Truck configuration. The technology is potentially modular and will have application in other vocational truck applications including many off-road vehicle platforms which will greatly enhance its potential energy and environmental benefits.

Reviewer 2

Electrification and architectures that are implementable and can be commercialized due to a reasonable TCO is key to the success of the VTO objectives.

Reviewer 3

It is hard to gauge the relevance of this project without some kind of independent, objective, background analysis to corroborate the alleged 20% fuel savings and reduction in 10,000 metric tons of greenhouse gases that will result from this project.

Otherwise, this particular project has relevancy to the categories of analysis, batteries, electrification, energy-efficient mobility systems and advances in materials.

Reviewer 4

This project addresses appropriate and pragmatic issues. Electrification will only be successful in fleet applications if it provides operators greater value than the vehicles they replace. This project is squarely focused on delivering fleet operators with greater value.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The outlined plan and resources seem reasonable.

Reviewer 2

The resources provided are reasonably sufficient for this project in light of the costs of SiC inverters, SiC converters and Li-ion battery packs as well as the dynamic modeling and re-design efforts.

Reviewer 3

There are appropriate resources based on the project plan.

Reviewer 4

The resources appear sufficient for the identified scope of the project. The project includes 25% contractor cost share.

Presentation Number: ace184
Presentation Title: Development of a Flex-Fuel Mixing Controlled Combustion System for Gasoline/Ethanol Blends Enabled by Prechamber Ignition
Principal Investigator: Adam Dempsey Marquette

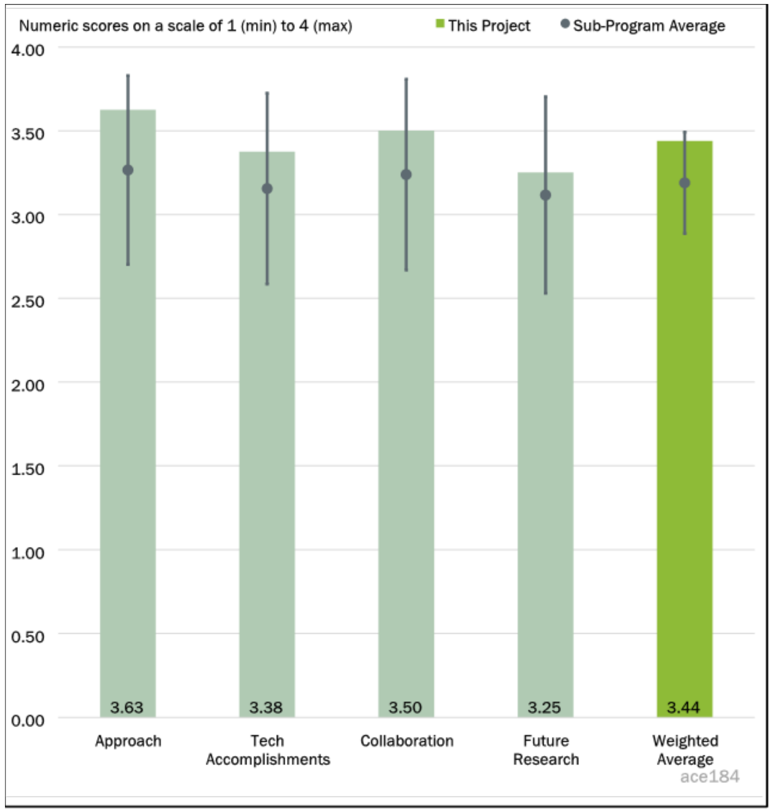

Figure 1-32 - Presentation Number: ace184 Presentation Title: Development of a Flex-Fuel Mixing Controlled Combustion System for Gasoline/Ethanol Blends Enabled by Prechamber Ignition Principal Investigator: Adam Dempsey Marquette

Presenter

Adam Dempsey Marquette

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The approach should overcome most barriers. The proposed timeline appears reasonable.

Reviewer 2

The project is in initial phases and is on-track with respect to schedule.

Reviewer 3

This is a new project, so this reviewer’s comments only encompass what has been planned and the organizational structure which has been set up which is just starting to operate. From that perspective it looks like it is off to a good start.

Reviewer 4

The overall approach is very sound with experiments and simulation. There is a good inclusion of fuel blendstocks for oxygenate blending (BOBs).

The reviewer suggests the project to consider showing the estimate of efficiency advantage of this system versus a traditional SI, high compression ratio engine. Also for maximum impact on CO_2 emissions reduction, the reviewer suggests to consider the use of a net-zero (renewable) gasoline or naphtha as the BOB, at least in a demo or conceptual activity.

Some mention of emission controls should be added, even if they are not needed. The reviewer suggests to consider a reference to prior work by Cummins on their 85% ethanol, 15% gasoline fuel blend (E85) engine of a few years ago, called “ETHOS”.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The project is in early phases but is producing excellent technical progress in the RCM experiments and simulation. The reviewer appreciates the simplified CO_2 emissions analysis in the backup slides, Slide 17.

Reviewer 2

The results are very descriptive and the progress made since the project started is very good.

Reviewer 3

Since the project just began, only limited progress is expected at this point. The initial modeling looks good, and will be an important part of the project in establishing strong pre-chamber combustion.

Reviewer 4

The research group has established a good foundation by verifying the fundamental basis for the project. The team has done significant CFD analyses projecting the improvements in GHG reduction using the proposed Flex-Fuel Mixing Controlled Prechamber concept, have performed RCM experiments to assess the ignition delay and soot reduction potential of the concept, and have coordinated with their collaborators to establish proof of concept engine experiments and development of the multi-cylinder testing of the final configuration of the prechamber insert.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The collaboration appears to be excellent, and referred to comments in Question 4.

Reviewer 2

The project looks to be well organized and has the potential to leverage the various strengths of its members.

Reviewer 3

The team is exceptional and has little room for improvement. Consider involving an organization engaged in “renewable gasoline” unless the project determines that 100% ethanol, 0% gasoline (E100) is the preferred path.

Reviewer 4

The reviewer thinks it is too early to assess collaboration and coordination across the project team.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said future work has clear milestones.

Reviewer 2

There are a lot of design and control variables (in addition to various fuel mixtures) surrounding the pre-chamber—hopefully this can be managed. Perhaps some structured modeling (e.g., design of experiment) can help find ‘best’ approaches.

Full pre-chamber CI engines generally have lower efficiency due to increased heat losses. Please include efficiency measurements and comparisons as the work proceeds.

Reviewer 3

The project has a clearly defined sequence of tasks with go/no-go gates along the way. The reviewer would have liked to see more effort put on trying to make this approach retrofittable to existing engines. See Question 10.

Reviewer 4

Overall, the plan is well-formed. Including TCO analysis toward the end of project is highly valuable. The need or lack thereof for an aftertreatment study needs explanation.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

Use of low carbon fuels/biofuels is a strong near-, mid-term, and long-term contributor to CO_2 emissions reduction. Seeking high engine efficiency and low emissions is very important and relevant in this path.

Reviewer 2

This topic addresses an important challenge in the CI engine context—using low cetane fuels in diesel engines.

Reviewer 3

Increasing engine efficiency is a path towards decreasing emissions.

Reviewer 4

The work is relevant, but the reviewer has concern about its practical application. This is for off-road vehicles. If the project is successful and new engines are built, the vehicles in which they are installed will most likely be incorporated into legacy fleets, one piece of farming equipment among many other conventionally powered pieces of equipment, for example. Would this cause logistic complications for the users? Now the user will have to have fueling infrastructure for legacy engines as well as for the new engines.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The resources appear to be good.

Reviewer 2

The presenter made no comment about being resource limited so the reviewer assumes the resources are sufficient.

Reviewer 3

Additional resources might be needed if a robust emission control system is needed.

Reviewer 4

It is difficult to discuss if resources are sufficient or not when the available funding across the DOE for the VTO ICE issues is so small.

Presentation Number: ace186
Presentation Title: Dynamic Skip Fire (DSF) on a Heavy-Duty Natural Gas Engine
Principal Investigator: Jay Shah, Cummins

Presenter

Jay Shah, Cummins

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

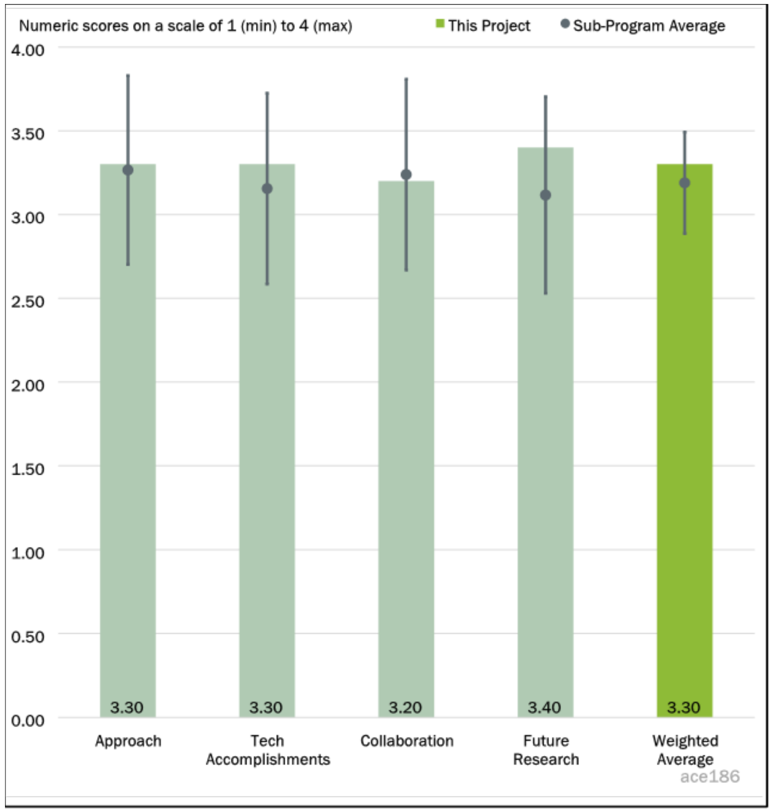

Figure 1-33 - Presentation Number: ace186 Presentation Title: Dynamic Skip Fire (DSF) on a Heavy-Duty Natural Gas Engine Principal Investigator: Jay Shah, Cummins

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

This is a well-designed project to apply dynamic skip fire (DSF) for a natural gas engine. The timeline is reasonably planned.

Reviewer 2

The DSF technology is a nice technology with proven, good results in SI engines and even some CI engines. Overall, the research is relevant to achieving efficiency with parity to diesel engines. However, the fuel efficiency benefits shown on Slide 2 are not huge, and may not be much if any greater than a “conventional” cylinder deactivation (CDA) approach, and the cost of the DSF system may not yield a favorable life-cycle cost. This needs a bit more investigation.

Reviewer 3

At a high level, the approach is appropriately defined.

Considering the vast scope of the project, the PI is encouraged to define the work plan in greater detail to ensure all milestones are achieved in a timely manner. For instance, a plan should be formulated for investigating some of the key technical challenges, including:

- Use of EGR: in view of the desire to operate at higher indicated mean effective pressure (IMEPs), EGR could be a key enabler for knock mitigation. Thus, it is important to ensure that appropriate levels of EGR are available at high IMEPs, especially when the DSF strategy is active. Based on the presentation it was not clear if EGR would be utilized when only one or two cylinders are firing.
- It is not clear if there is sufficient oil pressure to actuate the oil control valve at the lower engine speeds where this engine will often operate. If the oil pressure is insufficient, it may require the use of an auxiliary oil pump.
- Use of the two-stroke brake will cool down the TWC and potentially also make it oxygen rich. Based on the presentation it was not clear if this would adversely impact the ability of the TWC to meet the emissions targets.

Reviewer 4

This project is aligned with DOE's goal of reducing fuel consumption. In this case, the approach is to use natural gas engines that are able to meet future NO_x emission standards.

Overall, the technical barriers that are being overcome are relatively minor. There needed to be engineering work that integrated air brakes and DSF into the same engine, which had not been done before. However, DSF is, at this point, an established and proven technology that has been in production for several years with smaller engines. The biggest difference here seems to be that it is being applied to a larger engine.

Reviewer 5

The project currently focuses on the system integration of the CDA hardware to the engine. I believe the key technical barrier for a CDA system in a spark-ignition engine is going to be noise, vibration, and harshness (NVH) and oil consumption. The NVH evaluation seems to be only in the final phase with in-vehicle testing. The presentation does not mention if the NVH and oil consumption characteristics are going to be evaluated during the engine dyno phase where engine calibrations will be developed. The reviewer would encourage the addition of these factors into the engine dyno test phase if it is already not planned.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

Significant progress has been made with regards to designing the DSF valvetrain hardware into the engine, and combing that functionality with the engine braking technologies. Significant progress has also been made with the accompanying analysis on fuel savings with the technologies. There did not seem to be an extensive analysis of the emissions control catalyst, and the effect that the lean conditions and cooling would have on the catalyst performance. These conditions may not be part of some of the certification emissions cycles, but they will be part of the real-world emissions.

Reviewer 2

For a first-year project, the project's technical progress is excellent. The design of the overhead components is critical to this project and this important task has been completed. This reviewer would have expected some progress updates on the CDA hardware design. Is this task concurrently occurring with the overhead design or has this task not began yet?

Reviewer 3

The team has made excellent progress during the initial phases of the project. This has included simulation, hardware design, and controls development.

Reviewer 4

The project just kicked off a couple of months ago.

Reviewer 5

With the project having been kicked off a little over a month ago, the project team has not had sufficient time yet to make substantial progress yet.

In view of the short duration since project kick-off, completion of the valvetrain design indicated good progress and bodes well for the project.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

Very good teaming with Tula who have pioneered DSF and applied it to several types of engines.

Reviewer 2

The project has only two team members (Cummins and Tula). Both companies have a long and extensive working relationship and they have continued their partnership in this project as well.

Reviewer 3

The team consists of Cummins, Tula, and NREL. Given the extensive experience of Tula in commercializing DSF and Cummins in natural gas engine development, the team has the capability to accomplish the proposed tasks.

Reviewer 4

While Tula is identified as the project partner responsible for DSF controls integration, key personnel from Tula or key tasks assigned to Tula are not clearly defined in the report. Consequently, Tula's role and responsibility is not clear. Similarly, the role of NREL personnel on the project team is not clear.

Considering the complexity of the project, successful execution will require extensive collaboration between all project partners. For future reviews, it may be helpful to define the roles and responsibilities of all project partners in greater detail.

Reviewer 5

The project is being led by Cummins, and Tula is a hardware and technology vendor partnering on the project. The fundamental technology that Tula is bringing to this engine project is well established and is in production in smaller engines. The project team appears to be sufficient to perform the technical goals of the project, but there is no teaming with universities or diverse businesses or partners.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

Future work is well planned and likely to achieve its targets.

Reviewer 2

The remaining work for this engineering integration appears to be well planned and provides confidence that the result will be a fully functional prototype with integrated DSF technology.

Reviewer 3

The research plan is excellent and should result in improvements in fuel consumption in HD natural gas engines. Using RNG, these engines can contribute to the lowest CO_2 emissions of any HD freight propulsion system, along with their proven $ULNO_x$ ability. The reviewer suggests to check the cost effectiveness as work proceeds. The reviewer also suggests to check the emissions performance of the TWC with the skip fire impact on exhaust temperature.

Reviewer 4

The future research scope is well laid out. The project addresses all the important requirements such as hardware robustness demonstration and in-vehicle demo. It would help to identify some real-world challenges that may be observed with the CDA in natural gas engines.

Reviewer 5

The next steps, at least for the next one year, are clearly defined.

In view of the scale and complexity of this project, the project team is encouraged to develop a more detailed project plan to help ensure the various work streams are able to make progress in parallel. For instance, one of the deliverables for Budget Period 3 is a demo vehicle. This is a substantial undertaking and it may be beneficial to identify tasks in Budget Period 2, that may help with smooth execution of the vehicle build in the following budget period.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

Natural gas engines have been proven to achieve $ULNO_x$ and low PM and when using RNG can have zero or negative net carbon emissions. Hence the work here is highly relevant to extend RNG supplies by increasing ton-miles per diesel-gallon-equivalent (increased engine efficiency).

Reviewer 2

The objective is to design and develop DSF technology for HD natural gas engines to demonstrate a 6%-12% improvement in brake specific carbon dioxide emissions on low-loaded cycles while maintaining the capability to meet 0.02 g/hp-hr NO_x emissions. It supports the overall VTO subprogram objectives.

Reviewer 3

This project is aligned with DOE's goal of utilizing improvements in engine efficiency and utilization of alternative/low carbon fuels to improve vehicle efficiency and reduce greenhouse gas emissions.

Reviewer 4

This project supports the DOE mission to reduce fuel consumption, and does so in a direct way. The DSF is an established and proven technology to reduce fuel consumption at light loads, and does so within an acceptable NVH range.

Reviewer 5

The project is relevant in developing the next-generation high-efficiency, cleaner natural gas engines.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The funding for these projects should be reviewed and reassessed because of the general higher cost of everything in 2022. Funding may need increase to finish planned work.

Reviewer 2

Given the extensive experience of Tula in commercializing DSF and Cummins in natural gas engine development, the team has sufficient resources to achieve the stated milestones in a timely fashion.

Reviewer 3

Building prototype engines and demo vehicles is expensive. Thus, while the overall project budget appears to be significant, it is most likely reasonable.

Reviewer 4

Project resources appear to be sufficient.

Reviewer 5

An engine OEM and a Tier 1 controls development company are partners in this study. Both Cummins and Tula together have the technical expertise, manpower, and testing resources to complete this project successfully.

Presentation Number: ace187
Presentation Title: Opposed-Piston Two-Stroke Hybrid Commercial Vehicle System
Principal Investigator: Fabien Redon, Achates Power

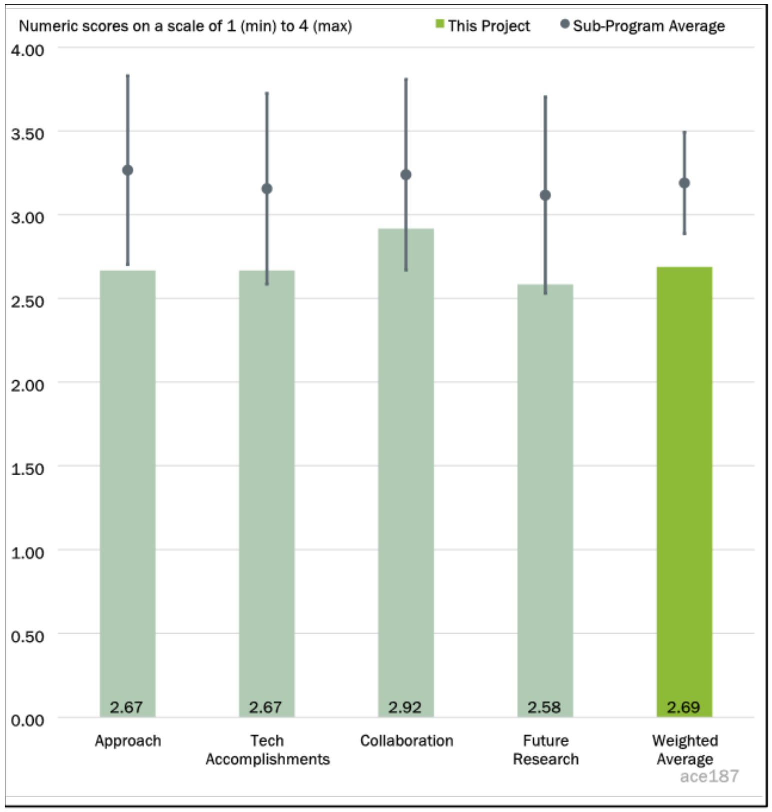

Figure 1-34 - Presentation Number: ace187 Presentation Title: Opposed-Piston Two-Stroke Hybrid Commercial Vehicle System Principal Investigator: Fabien Redon, Achates Power

Presenter

Fabien Redon, Achates Power

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 17% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

An effective approach at addressing the barriers was presented that builds on improvements with hybridization with OP2S technology and the integration of H_2. The previous advancements that are being leveraged for this work as a starting point were well articulated. The objectives of the project are matched to the barriers and will have tangible outcomes.

Reviewer 2

The use of molecular H_2 has the potential to reduce GHG emissions (depending upon sourcing of the H_2). However, operating H_2 in compression ignition is a bit risky, in that there is not much work in the literature on this topic. Given the architecture of the OP2S engine, it is plausible to explore CI H_2.

However, hybridization of MD/HD trucks is fraught with challenge as well. If extensive emissions controls are needed - almost certainly with ULNO$_x$ - adding the NO$_x$ catalyst along with adding a complete high voltage electric system (600+V of direct current) will certainly add to the cost of the vehicle. The California Air Resources Board (CARB) and other regulatory agencies have stated that ICE solutions in vehicles will not count toward any ZEV requirement. The challenge in this project will be to balance performance and emissions with the cost of the vehicle. How much battery and electric drive are needed, how large is the engine, and how much fuel will get consumed? The devil is truly in the details here, and not many details were presented in the slide deck or the Q&A session.

Reviewer 3

The timeline is reasonable based on recent past engine work on Achates Power's 10.6-liter two-stroke engine which sets the tone for this two-year project. This is a new start and not even the hybrid architecture has been chosen which will be one key component toward driving any fuel economy gains along with of course any engine system improvements. This project hopefully will demonstrate the possibility of an OP2S in a HEV powertrain to improve current state-of-the-art benchmarks by taking advantage of mid-load efficiency capability of OP2S engines in conjunction with strategic use of on-board energy storage. Further, exploring potential H_2 use will hopefully scratch the surface on alternative fuels use in OP2S engines.

Reviewer 4

There seem to be two sub-projects with two different sets of barriers included in this project.

The first sub-project is the commercial HEV. For this, the project seemed to focus on engine combustion improvements. There was not any information about the hybrid engine architecture. The reviewer assumes that this is a hybrid electric configuration, but there was not even that level of detail (for example, could it be hydraulic hybrid? Could it be pneumatic hybrid?). There was a stated goal of 13% fuel consumption reduction, but no indication of how. Hybrid integration work was a large part of the SuperTruck II programs, and that integration required a major effort. It would be helpful to understand what the targeted battery pack would be, targets from regenerative braking, etc. 13% is a very specific target, and while it is early in the project, there should be an initial plan in these regards to have given them the confidence that they could hit that target, even if the plan changes as the project progresses. So, the work and planning towards the hybrid architecture seems to be very thin at this point. Further, there seems to be a lot of effort centered around Achates collecting data from Achates' engine that was integrated into the Walmart truck. This reviewer understands a need to collect some additional/different data, but the reviewer asks if all of the steady state data should already be in-hand? Should they already have some/most of the transient data? Should they already have a powertrain and aftertreatment model since this has already been integrated in a prior project? This entire effort seems redundant to information they should already have.

The other sub-project that seems to be included here is the H_2 engine development project. There are no milestones that mention anything about a H_2 engine, nor is there any indication in the title of the project that this is related to a H_2 engine. That makes this reviewer wonder if the H_2 work was part of the initial scope of work, or if it was a part of the project that Achates added in later. There was no discussion in the presentation or in the slides about this, and whether this was a change in focus directed by DOE. There is no doubt that H_2 engines are of interest, especially in light of the DOE decarbonization focus. However, while all of the project milestones seem focused on the hybrid part of the project, a lot of resources appear to be focused on the H_2 part of the project. Completing just the hybridization effort in a thorough and rigorous manner that reflect real use cases will take a lot of effort, and that appears to be the original goal of this project based on the milestones.

Reviewer 5

This is a new project. The roles of the partners are not clear. The project is supposed be for hybrid commercial vehicles but there is not much discussion of the hybrid part of the work. The baseline vehicle is not a hybrid. It would have been great to have a hybrid vehicle to test as a baseline.

Reviewer 6

It is recognized that the project is just getting started, so plans may be in development. The vision and details of the hybrid powertrain are not adequate to fully assess the path. Overall, the approaches of hybrid power and low-carbon fuels are on the path to support VTO objectives.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

This is a new start project which makes progress assessment difficult. But, the project is out of the gates fast based on past 10.6-Liter testing.

Reviewer 2

The project is only 10% complete, so it is difficult to evaluate progress. The plan and the partners appear to be sound, although some additional detail as to the level of hybridization that is planned to be explored would have been helpful.

Reviewer 3

This project is being reviewed early in the project cycle with a March 2022 start date. The H_2 CI approach selection and the collection of steady-state and transient data are underway.

Reviewer 4

This specific project is in a very early phase, although the technology in general has received support from DOE for many years. The improvement in efficiency noted over the previous, 10.6-liter opposed piston HD engine is good progress. However, the BSFC and CO_2 data should be compared to the state-of-the-art diesel engines, not just previous OP2S engines. The reviewer recommends showing fuel consumption and CO_2 data in comparison to EPA certification data for commercial engines of similar size. Most of the technical achievements are yet to come.

Reviewer 5

This is a new project.

Reviewer 6

In some regards, it is difficult to fully grasp the scope of the project plan because of the two different projects being merged into the single project, and this project is just getting started.

The technical accomplishments associated with the hybridization effort are minimal. This was limited to engine improvements (aftertreatment, air system, and friction). There was not any discussion of the hybridization approach, operating strategies, etc. There was no discussion of what the target battery size would be, if it would enable downsizing, or how it would affect the engine operating duty cycle. This reviewer understands that Clemson University will be doing some of this work, but their approach was not covered. It seems that there should have been a lot of prior existing steady state and transient data for the project team to work with, considering that this is an Achates engine and they performed the vehicle integration, and that there should already be a powertrain and aftertreatment model as a starting point. There should be technical accomplishments that can be made immediately without having to spend resources reinventing these data and modeling tools.

In contrast, there were three accomplishment slides associated with H_2 engines. Again, there is nothing in the milestones about a H_2 engine and this reviewer is wondering if it was part of the original scope as it is not in the title or milestones. There seems to be a lot of effort, both ongoing and planned, focused on H_2. The future work indicated that two different versions of H_2 single cylinder engines will be built and there will be a lot of testing. What project resources will be left to address the main hybridization focus of the project?

Question 3: Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1

This team looks to be well-suited to perform the tasks to which each partner is assigned. There is a good combination of industry and university partners. Each partner has clearly defined roles and responsibilities.

Reviewer 2

This is a solid team assembled with clear indications of partner coordination and specific contributions with industry and universities leveraging signature strengths of each. It is not clear which partners will be responsible for the specific tasks in the proposed future research and how the collaboration will enhance that work. Specifically, it was not clear what exactly the Clemson University and Isuzu roles were. University of Wisconsin’s roles were provided verbally.

Reviewer 3

The partners to Achates are highly capable and the roles are included in the presentation. Whether the partners contributed to the data in this presentation was not very clear. This can be easily improved. There is apparently a broad working group on opposed piston H_2 engines involving more partners. The reviewer may have missed that, if mentioned. It does not seem to be in the slides. The reviewer suggests to consider clarifying at a future opportunity.

Reviewer 4

It is not clear what each partner does. Slide 11 describes some of it but there needs to be more linkage to the previous slides when the approach is explained. Moreover, what University of Wisconsin is doing for this project seems to be exactly the same as they did with the same team on ACE166. How is their role different for this project?

Reviewer 5

Again, this is a new start, but the tasks of the university partners are very clear and it appears early on that activities have begun in H_2 combustion and vehicle system modeling and simulation.

Reviewer 6

There is a collaboration team consisting of Achates, Clemson University, University of Wisconsin, and Isuzu. The team appears to have a good working relationship and good delineation of responsibilities. This appears to be the same research team associated with the other DOE project being led by Achates, including the same PIs at each organization, so it is somewhat disappointing that the team was not altered to help separate responsibilities and to bring in different skill sets needed for hybridization. This team seems to be heavy on engine and vehicle systems expertise, and light on hybridization and electrification expertise. The reviewer would have preferred to see some additional expertise on batteries, power electronics, electric machines, and controls included. If those skill sets are represented by the teams, it did not come across during the presentation, and it does not appear to be a team with the deep expertise of electrification needed for a hybridization project.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The plan addresses most of the technical barriers and challenges. However, it would have been preferable to see Isuzu play a more active role in the hybridization portion of the project, since they actually make vehicles and would be in a position to evaluate the effectiveness of the hybrid system. The big challenge in this project is initiation and control of H_2 combustion in a CI system. There simply is not much work done here and the risk is fairly significant for such a system to not work as intended. A bit more detail on a mitigation strategy if H_2 CI fails would have been prudent.

Reviewer 2

It is not clear which partners will be responsible for the specific tasks in the proposed future research and how the collaboration will enhance that work.

Reviewer 3

The overall approach is okay, but is short on details. It appears that the hybrid system work is mostly simulation, which is a rather soft outcome. The H_2 combustion work will be interesting.

Reviewer 4

The future work feels like more of engine research rather than an engine for a HEV research. It would be good to have more emphasis on the hybrid portion of the drivetrain, too.

Reviewer 5

The proposed future research is focused on addressing project barriers and objectives. It includes a combination of simulation to develop a single cylinder engine H_2 combustion system, controls development for performing engine-in-the-loop HEV powertrain assessment, and eventual single cylinder engine testing for real world H_2 assessment. One key part of the project is the HEV powertrain assessment and thus it will be critical that the vehicle OEM ensures realistic assumptions are made during the vehicle model development portion of the project. Overall, based on funding level and timing this is an aggressive project that will give a decent initial OP2S-HEV powertrain assessment.

Reviewer 6

There is a lot of effort on areas where this reviewer does not think there should be effort, and too little effort on other areas.

Regarding the collection of engine and aftertreatment data, the team should have an extensive amount of data and baseline models that they could use as a starting point. The reviewer can certainly see the need for some additional data or model refinements, but there appears to be too much effort to collect data and build models that should already exist in some form.

Regarding the H_2 engine, there are no milestones about a H_2 engine, making this reviewer wonder if it was part of the original project. The future work includes designing and procuring a H_2 combustion system for a single cylinder engine in both Fiscal Year 2022 and Fiscal Year 2023, testing the H_2 engine to make H_2 combustion models, and using the H_2 engines to refine the combustion model. There are also major costs involved in installing a H_2 engine. Considering that this will take major resources and there are no milestones associated with it, this reviewer wonders if there will be sufficient resources left to do the hybridization work.

Finally, too few of the elements of the proposed work were focused on the hybridization effort and meeting the hybridization milestones.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The project is relevant because it addresses ULNO$_x$, GHG and vehicle efficiency improvement.

Reviewer 2

The project is well suited to decarbonization goals and freight efficiency goals.

Reviewer 3

The primary relevance is the assessment of whether a zero-carbon fuel is compatible with this engine configuration.

Reviewer 4

The project is relevant but needs to show more hybrid work.

Reviewer 5

Yes, it supports VTO objectives toward improving heavy vehicle fuel economy while meeting emission standards. Exploring the OP2S fuel consumption characteristics at medium load coupled with likely a mild parallel hybrid should directly address VTO objectives from an R&D perspective.

Reviewer 6

Yes, both hybridization and H_2 engines are relevant to the VTO subprogram objectives associated with reducing fuel consumption and decarbonization.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The resources appear to be sufficient to ensure the successful outcome of this project.

Reviewer 2

Total project funding seems sufficient to meet the goals considering previous advancements being leveraged as a starting point.

Reviewer 3

The project would benefit from clearly showing the annual accomplishments made with various annual resources.

Reviewer 4

This is a small project in reference to expectations. It appears there are sufficient resources to make an O2PS-HEV assessment though such an effort could realistically require further funding as experimental work gets underway.

Reviewer 5

It appears to this reviewer that there were enough resources allocated to this project to launch a H_2 engine development project inside of this project, even though the title and the milestones are not related to H_2. A H_2 engine development program takes a lot of resources, and if this was done with funds for this project, the funding was excessive.

Reviewer 6

University of Wisconsin seems to be doing the exact same thing they did for ACE166. The difference needs to be explained.

Acronyms and Abbreviations

21CTP	21st Century Truck Partnership
3-D	Three-dimensional
ACE	Advanced Combustion Engines
ACI	Advanced compression ignition
AMR	Annual Merit Review
ANL	Argonne National Laboratory
BEV	Battery-electric vehicle
BOB	Blendstocks for oxygenate blending
BP	Budget Period
BSFC	Brake specific fuel consumption
BTE	Brake thermal efficiency
CARB	California Air Resources Board
CDA	Cylinder deactivation
Ce	Cerium
CeO_2	Ceria
CFD	Computational fluid dynamics
CFR	Cooperative Fuel Research
CI	Carbon intensity
CI	Compression-ignition
CO	Carbon monoxide
CO_2	Carbon dioxide
COVID-19	Coronavirus disease 2019
CRADA	Cooperative research and development agreement
CRT	Continuously regenerating trap
CS	Cooled spray
CT	Computerized tomography
Cu	Copper
DC/DC	Direct current/direct current
DFI	Ducted fuel injection
DI	Direct injection
DME	Dimethyl ether

DNS	Direct numerical simulation
DOC	Diesel oxidation catalyst
DOCF	Combined diesel oxidation catalyst and diesel particulate filter
DOE	U.S. Department of Energy
DPF	Diesel particulate filter
DPF	Diesel particulate filter
DRIFTS	Diffuse reflectance infrared Fourier transform microscopy
DSF	Dynamic skip-fire
E10	10% ethanol, 90% gasoline fuel blend
E100	100% ethanol, 0% gasoline fuel blend
E85	85% ethanol, 15% gasoline fuel blend
EERE	Office of Energy Efficiency and Renewable Energy
EGR	Exhaust gas recirculation
EPA	U.S. Environmental Protection Agency
EPR	Electron paramagnetic resonance spectroscopy
FOA	Funding opportunity announcement
FRESCO	Fast, Robust Engine Simulation Code
FTE	Freight-ton efficiency
FTIR	Fourier-transform infrared spectroscopy
FTP	Federal Test Procedure
FY	Fiscal Year
g	Grams
g/hp-hr	Gram per horsepower-hour
GHG	Greenhouse gas
GM	General Motors
GT-Power	Gamma Technologies - Power
H_2	Hydrogen
HC	Hydrocarbon
HD	Heavy-duty
HEV	Hybrid electric vehicle
HIL	Hardware-in-the-loop
HVAC	Heating, ventilation, and air conditioning

HVO	Hydrotreated vegetable oil
ICE	Internal combustion engine
IMEP	Indicated mean effective pressure
ITE	Indicated thermal efficiency
L	Liter
lb	Pound
LBNL	Lawrence Berkeley National Laboratory
LCA	Life-cycle analysis
LES	Large eddy simulation
Li-ion	Lithium-ion
LLCF	Low life-cycle carbon fuels
LO	Light-off
LPG	Liquified petroleum gas
LTHR	Low temperature heat release
LTP	Low-temperature plasma
MD	Medium-duty
ML	Machine learning
MON	Motor octane number
MTU	Michigan Technical University
N_2O	Nitrous oxide
NH_3	Ammonia
NO	Nitric oxide (nitrogen monoxide)
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
NRC-Canada	National Research Council-Canada
NREL	National Renewable Energy Laboratory
NVH	Noise, vibration, and harshness
O	Atomic oxygen
OEM	Original equipment manufacturer
OP2S	Opposed piston two-stroke
ORNL	Oak Ridge National Laboratory
PAH	Polycyclic aromatic hydrocarbon

Pd	Palladium
PEC	Pareto-efficient combustion
PFR	Plasma flow reactor
PGM	Platinum group metals
PI	Principal investigator
PI	Principal Investigator
PM	Particulate matter
PNNL	Pacific Northwest National Laboratory
PRF	Primary reference fuels
Q&A	Question and answer
R&D	Research and development
RANS	Reynolds-averaged Navier-Stokes
RCM	Rapid compression machine
RDD&D	Research, development, deployment, and demonstration
Rh	Rhodium
RNG	Renewable natural gas
ROI	Return on investment
RON	Research octane number
rpm	Revolutions per minute
RWA	Real-world aging
SAC	Single-atom catalyst (catalysis)
SAE	Society of Automotive Engineers
SCE	Single-cylinder engine
SCR	Selective catalytic reduction
SCRF	Selective catalytic reduction on filter
SET	Supplemental Emissions Test
SI	Spark ignition
SiC	Silicon carbide
SNL	Sandia National Laboratories
SO_x	Sulfur oxides
SwRI	Southwest Research Institute
TCO	Total cost of ownership

TWC	Three-way catalyst
U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability
UCONN	University of Connecticut
$ULNO_x$	Ultra-Low Nitrogen Oxides
UNM	University of New Mexico
USCAR	United States Council for Automotive Research
UW	University of Wisconsin
V	Volt
VTO	Vehicle Technologies Office
WHR	Waste heat recovery
WSU	Washington State University
WVU	West Virginia University
ZEV	Zero-emission vehicle

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2. Battery R&D

The Vehicle Technologies Office (VTO) supports research, development, deployment, and demonstration (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. The office's investments leverage the unique capabilities and world-class expertise of the national laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies and systems (including automated and connected vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement); combustion engines to reduce greenhouse gas (GHG) emissions; and technology deployment and integration at the local and state level. In coordination with the other offices across the Office of Energy Efficiency and Renewable Energy (EERE) and the U.S. Department of Energy (DOE), the Vehicle Technologies Office advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

The VTO Battery R&D subprogram supports the decarbonization of transportation across all modes, serves to increase American advancement/manufacturing of battery technology, and creates good paying jobs with the free and fair chance to join a union and bargain collectively. The subprogram supports research with partners in academia, national laboratories, and industry covered under the Energy Storage Grand Challenge key priority and distinct crosscuts. The Energy Storage Grand Challenge encompasses R&D across energy storage including the discovery of alternative lithium battery materials, processing for raw materials, development of advanced battery cells, discovery of innovative cell manufacturing techniques, and battery recycling. The Critical Minerals crosscut aims to reduce or eliminate cobalt and nickel in lithium battery cathode materials, develop substitutes for graphite such as silicon composite anodes and lithium metal anodes, and develop advanced recycling and processing through scale up of bench-scale recycling processes and innovative separation processes seedlings. The Advanced Manufacturing crosscut is focused on coordination with the Advanced Manufacturing Office for joint projects scaling up solid state battery materials and lithium metal electrode processing technologies addressing critical materials for batteries.

The Battery R&D activity supports early-stage R&D of high-energy and high-power battery materials, cells, and battery development that can enable industry to significantly reduce the cost, weight, volume, and charge time of PEV batteries. This activity is organized into sub-activities: advanced battery materials research, advanced battery cell R&D, and battery recycling R&D. Advanced battery materials research is coordinated with the Critical Minerals Initiative and includes: early-stage research of new lithium-ion cathode, anode, and electrolyte materials (currently accounting for 50-70 percent of PEV battery cost) and the development of "beyond lithium-ion" technologies, such as lithium metal anodes, solid-state electrolytes, and sulfur-based cathodes, that have the potential to significantly reduce weight, volume, and cost by three times, with a target of $60/kWh. Advanced battery cell R&D includes: 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; and high-fidelity battery performance, life, fast charging, and safety testing of innovative battery technologies including recycled material and cells. Battery recycling R&D includes the development of innovative battery materials recycling and reuse technologies, and the Lithium-Ion Battery Recycling Prize, both to assure sustainability and domestic supplies of key battery materials and minerals.

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
bat359	Status and Challenges of Electrode and Electrolyte Materials for High Energy Cells	Stanley Whittingham (Binghamton University)	2-7	3.67	3.50	3.67	3.50	3.56
bat360	Cathodes Beyond Lithium Nickel Manganese Cobalt Oxide (NMC) 811	Arumugam Manthiram (University of Texas at Austin)	2-12	3.83	3.75	3.25	3.33	3.66
bat361	Understanding and Improving Lithium Anode Stability	Yi Cui (Stanford University / SLAC National Accelerator Laboratory)	2-18	3.50	3.38	3.50	3.50	3.44
bat362	High Capacity S Cathode Materials	Prashant Kumta (University of Pittsburgh)	2-23	3.50	3.30	3.50	3.50	3.40
bat364	Synergistic Effects of Electrode and Electrolyte Materials for High Energy Lithium Cells	Jihui Yang (University of Washington)	2-29	3.20	3.30	3.60	3.30	3.31

bat365	Stabilizing Lithium Metal Anodes by Interfacial Layer and New Electrolytes	Zhenan Bao (Stanford University / SLAC National Accelerator Laboratory)	2-34	3.30	3.20	3.40	3.10	3.24
bat366	Manufacturing and Validation of Lithium Pouch Cells	Mei Cai (General Motors Company)	2-40	3.50	3.38	3.88	3.50	3.48
bat367	Multiscale Characterization Studies of Lithium Metal Batteries	Peter Khalifah (Brookhaven National Laboratory)	2-44	3.67	3.75	3.50	3.58	3.68
bat368	Full Cell Diagnostics and Validation to Achieving High Cycle Life	Eric Dufek (Idaho National Laboratory)	2-49	3.38	3.50	3.50	3.50	3.47
bat369	High Energy Rechargeable Lithium-Metal Cells, Design, Fabrication and Testing	Jie Xiao (Pacific Northwest National Laboratory)	2-52	3.88	4.00	3.75	3.63	3.89
bat496	Silicon Consortium Project: Advanced Characterization of Silicon Electrodes	Robert Kostecki (Lawrence Berkeley National Laboratory)	2-56	3.38	3.13	3.38	3.25	3.23
bat497	Silicon Consortium Project: Electrochemistry of Silicon Electrodes	Christopher Johnson (Argonne National Laboratory)	2-60	3.13	2.88	3.38	3.00	3.02
bat498	Silicon Consortium Project: Next-Generation Materials for Silicon Anodes	Nathan Neale (NREL)	2-64	3.63	3.50	3.63	3.63	3.56

bat499	Silicon Consortium Project: Mechanical Properties of Silicon Anodes	Katherine Harrison (Sandia National Laboratories)	2-68	3.25	3.25	3.50	3.50	3.31
bat500	Silicon Consortium Project: Science of Manufacturing for Silicon Anodes	Gabriel Veith (Oak Ridge National Laboratory)	2-72	3.70	3.50	3.70	3.50	3.58
bat501	Integrated Modeling and Machine Learning of Solid-Electrolyte Interface Reactions of the Silicon Anode	Kristin Persson (Lawrence Berkeley National Laboratory)	2-76	3.63	3.38	3.63	3.50	3.48
bat523	Development of Long Life Lithium and sulfurized polyacrylonitrile (SPAN) Cells	Ping Liu (University of California-San Diego)	2-79	3.80	3.50	3.60	3.40	3.58
bat524	Advanced Electrolytes for Lithium Metal Batteries	Chunsheng Wang (University of Maryland)	2-85	3.50	3.63	3.63	3.50	3.58
bat525	Fluorinated Solvent-Based Electrolytes for Low Temperature Lithium-ion Battery	John Zhang (Argonne National Laboratory)	2-89	3.25	3.25	3.25	3.25	3.25
bat526	Ethylene Carbonate-lean Electrolytes for Low-Temperature, Safe Lithium-ion Batteries	Bryan McCloskey (Lawrence Berkeley National Laboratory)	2-92	3.33	3.17	3.00	3.00	3.17
bat527	Synthesis, Screening and Characterization of Novel Low-Temperature Electrolyte for Lithium-ion Batteries	Xiao-Qing Yang (Brookhaven National Laboratory)	2-95	3.17	3.17	3.17	3.17	3.17

bat528	Structurally and Electrochemically Stabilized Silicon-rich Anodes for Electric Vehicle Applications	Murali Ramasubramanian (Enovix)	2-98	3.60	3.50	3.30	3.20	3.46
bat529	Rationally Designed Lithium-Ion Batteries Towards Displacing Internal Combustion Engines	Rick Costantino (Group 14 Technologies)	2-102	3.40	3.60	3.30	3.00	3.44
bat530	Ultra-Low Volume Change Silicon-Dominant Nanocomposite Anodes for Long Calendar Life and Cycle Lif	John Tannaci (Silanano)	2-107	3.00	3.00	2.90	2.60	2.94
bat531	Solid State Lithium-ion Batteries Using Silicon Composite Anodes	Pu Zhang (Solid Power Battery)	2-112	3.50	3.38	3.13	3.00	3.33
bat532	Electrolytes with Lithium-ion Batteries with Micro-sized Silicon Anodes	Chunsheng Wang (University of Maryland)	2-116	3.25	3.50	3.88	3.38	3.47
bat533	Fluorinated Local High Concentration Electrolytes Enabling High Energy Density Silicon Anodes	Amy Marschilok (Stony Brook University)	2-122	3.50	3.25	3.38	3.38	3.34
bat534	Devising mechanically compliant and chemically stable synthetic solid-electrolyte interphases on silicon	Pierre Yao (University of Delaware)	2-127	3.00	2.75	2.88	3.25	2.89

bat553	Understanding solid electrolyte interphase (SEI) reactions in Lithium metal and Lithium-Sulfur batteries	Perla Balbuena (Texas A&M University)	2-132	3.25	3.38	3.00	3.25	3.28
bat554	Fabricate and Test Solid-State Ceramic Electrolytes and Electrolyte/Cathode Laminates †	Mike Tucker (LBNL)	2-136	3.17	2.83	3.17	3.00	2.98
Overall Average				**3.45**	**3.38**	**3.42**	**3.31**	**3.39**

† Denotes poster presentation.

Presentation Number: bat359
Presentation Title: Status and Challenges of Electrode and Electrolyte Materials for High Energy Cells
Principal Investigator: Stanley Whittingham, Binghamton University

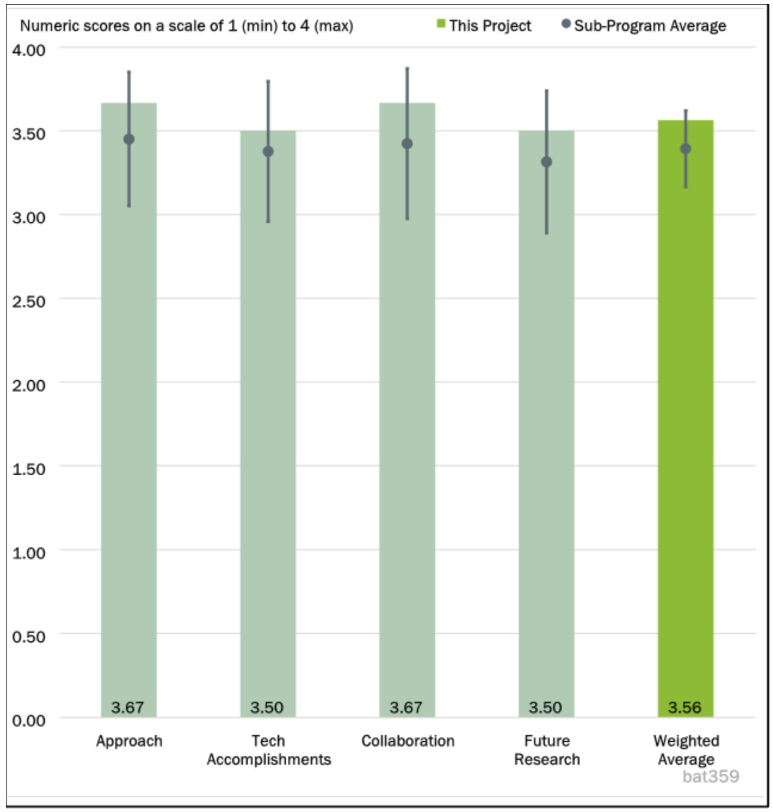

Figure 2-1 - Presentation Number: bat359 Presentation Title: Status and Challenges of Electrode and Electrolyte Materials for High Energy Cells Principal Investigator: Stanley Whittingham, Binghamton University

Presenter

Stanley Whittingham, Binghamton University

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 17% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer interprets the aim of the project as the following: Can we increase the energy density of Li/NMC cells by overcharging the cathode while still maintaining acceptable cycle life and safety? To answer this question, this project studies the thermal reactivity of an NMC811 cathode in the presence of different liquid electrolytes. The work presented is a great start towards answering this question.

Reviewer 2

The reviewer commented the principal investigator (PI) and team are working to address major technical barriers associated with nickel (Ni)-rich NMC both at the materials and cell component level. Both in situ calorimetry and ex-situ DSC provides critical on the exothermicity of electrolyte-electrode reaction at higher voltages and the effect of additives and coatings.

Reviewer 3

The reviewer said this project is targeted at developing high-energy cathode materials with a specific capacity of greater than 220 mAh/g for Li metal batteries. The team is aiming to improve the cycling and thermal stability of Ni-rich cathodes through a combination of surface coating and lithiation, which sounds promising.

Reviewer 4

The reviewer commented the team addressed the barrier of improving energy density by first looking into each individual component and their interfaces, starting from leveraging the state-of-the-art battery material candidates. Their thermal stability and reactivity are investigated by thermal analysis and operando studies.

Reviewer 5

The reviewer said that though the technical barriers are addressed by the author, the following questions should be considered. Does the niobium (Nb) coating work in LiFSi only, and what happens with $LiPF_6$?. The reviewer noted that it is good to show and compare the improvement due to Nb coating for LiFSi and $LiPF_6$.

Reviewer 6

The reviewer said the team has thoroughly addressed the technical barriers, and the approaches are reasonable. One question is for the thermal studies The reviewer noted it looks as though most of the experiments will be conducted with a coin cell. The heat mass could lead to much noise. The reviewer said the team might also consider the experiments with pouch cells, which could generate more reliable data. In addition, the team might also test the thermal behaviors at different stage of battery life.

*Question 2: **Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.***

Reviewer 1

The reviewer said the Nb coating is certainly interesting and it shows improvement for the retention capacity. It is also important to show what is the cycling capacity in terms of mA/hr for the improved retention capacity.

Reviewer 2

The reviewer said the thermal benchmarking of bare cathodes versus coated cathodes provides important information about the role of coatings, reactivity with cell components, and parasitic reaction that generated heat. Safety evaluation for high Ni-content NMC cathodes is critical. The reviewer noted that Nb-containing NMC show better performance, and the team has developed a method to incorporate Nb at the lithiation stage, thus avoiding an extra synthesis step.

The reviewer pointed out that more mechanistic studies are needed to understand the role of Nb in improving the performance of Ni-rich NMC. Is Nb mainly on the surface of the cathode in some oxide form or in the bulk cathode particle. Is the coating uniform or random morphology? The reviewer suggested that the chemical formula of electrolytes and additives should be elaborated and described in detail to analyze and interpret the DSC studies.

Reviewer 3

The reviewer said the team has enabled operation of a Ni-rich cathode with an ultrahigh Ni content of 90% for 200 cycles without obvious fading via Nb coating/substitution. The results look very impressive. It could potentially lead to a much-improved energy density and cycle life of Li metal batteries for Battery500.

Reviewer 4

The reviewer said the team investigated several pairs of electrolytes/cathodes for the thermal analysis, and the team found the Nb coating showed improved cycling stability of high Ni NMC. Will the team check the thermal stability of the Nb-coated high Ni NMC with electrolytes and see potential improvement? Will the team link the thermal analysis with cycling stability data in the future studies?

Reviewer 5

The reviewer said this project demonstrated the experimental capability to measure the thermal reactivity of a NMC811 cathode in a variety of different electrolytes, and provided a few points for consideration:

A commercially relevant cathode active material (CAM) + electrolyte baseline should be established. Many cell suppliers use a proprietary CAM coating and electrolyte formulation. If the goal is a systems approach, then the CAM/electrolyte system should include a CAM coating.

The reviewer said increasing voltage cutoff will exacerbate transition metal dissolution and increase crosstalk with the Li-metal anode, which may reduce cycle life. Are there plans to consider this issue in addition to CAM/electrolyte reactivity? The reviewer understands that some of the electrolyte formulations are proprietary. For the formulations that are known, what fundamental mechanisms are thought to influence the results? M47 and ED2 cause significantly higher heat generation, for example. Why is that?

Reviewer 6

The reviewer said it looks the baseline selection needs to be improved. For example, the team has shown the cycle stability of NMC9055 can be improved by doping Nb; however, the baseline performance is worse than the commercial product.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said the PI and team are fully integrated and demonstrated great teamwork.

Reviewer 2

The reviewer remarked the team has done an excellent job to collaborate with other institutions, and it is well organized.

Reviewer 3

The reviewer commented the team collaborates well with the Battery500 consortium team.

Reviewer 4

The reviewer said the team has very good collaborations among different institutes, which is reflected from highly productive publications.

Reviewer 5

The reviewer pointed out that this project utilizes advanced, sometimes proprietary, liquid electrolytes from a variety of sources so the collaborative nature of this project is on point. The reviewer said CAM from other DOE projects should be evaluated in addition to the commercial Targray baseline. For example, the NATM from BAT360 should be evaluated.

Reviewer 6

The reviewer said collaboration within the project team is good, but that no industry contributions are specified. This project seems to collaborate with national labs and other external entities, but it is yet to be done. The reviewer cited as examples LATP coating (Yang) on separator in LiFSi can be combined with Nb coating and tested, and the addition of $LiPO_2F_2$ (Peter) works in $LiPF_6$. Can it work with LiFSi? The reviewer said if Nb coating works for $LiPF_6$ then the addition of $LiPO_2F_2$ (Peter) can also be tested.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer remarked proposed future research can achieve its target to some extent. It might be a challenge to reach 500 WHr/Kg and it depends on the approach for full cell considering the improvements with other team members.

Reviewer 2

The reviewer said the team has raised the most critical issues. It would be great if the tests can be done in the pouch cell to for better validation, besides the coin cells.

Reviewer 3

The reviewer remarked the future work of the team will support Battery500 Keystone 2 and 3, develop cathode reactivity strategic plan and provide better cathode materials for the Battery500 projects.

Reviewer 4

The reviewer said the proposed research has covered most of the barriers of Ni-rich cathodes at the particle, material, and electrode level. The reviewer noted that air stability of the Ni-rich cathode, particularly when the Ni content is more than 90%, should be taken care of.

Reviewer 5

The reviewer remarked the proposed future work makes sense; however, it is not clear how the data presented here will be applied. The reviewer asked how will the data help set cutoff voltage, and will the data be used in continuum cell modeling efforts?

Reviewer 6

The reviewer found that the proposed future work is a little broad—needs more specificity to exact technical challenges that need to be addressed. Right now, it is at a high level.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said yes, it supports overall VTO program objectives.

Reviewer 2

The reviewer remarked overall, the project advanced VTO goals for enabling advanced Li-metal batteries both in terms of safety and performance.

Reviewer 3

He reviewer said yes, it supports the overall VTO objectives.

Reviewer 4

The reviewer remarked the project definitely supports the VTO objectives in developing 500 Wh/kg batteries for automotive application.

Reviewer 5

The reviewer commented project objectives align well with the VTO objectives in improving Li-ion battery performance with no sacrifice of scalability.

Reviewer 6

The reviewer pointed out that understanding the thermal reactivity of Li-metal batteries is of critical importance.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer commented the team led by Prof. Whittingham is the pioneer in cathode development.

Reviewer 2

The reviewer said proposed project milestones are achieved in a timely fashion.

Reviewer 3

The reviewer said resources are adequate.

Reviewer 4

The reviewer remarked yes, the collaboration among national labs, universities, and electric vehicle (EV) manufactures is very critical to cover the fundamental understanding and practical implementation.

Reviewer 5

The reviewer does not see any resource problems the team may encounter in pursuing the proposed work.

Reviewer 6

The reviewer said project resources are sufficient.

Presentation Number: bat360
Presentation Title: Cathodes Beyond Lithium Nickel Manganese Cobalt Oxide (NMC) 811
Principal Investigator: Arumugam Manthiram, University of Texas at Austin

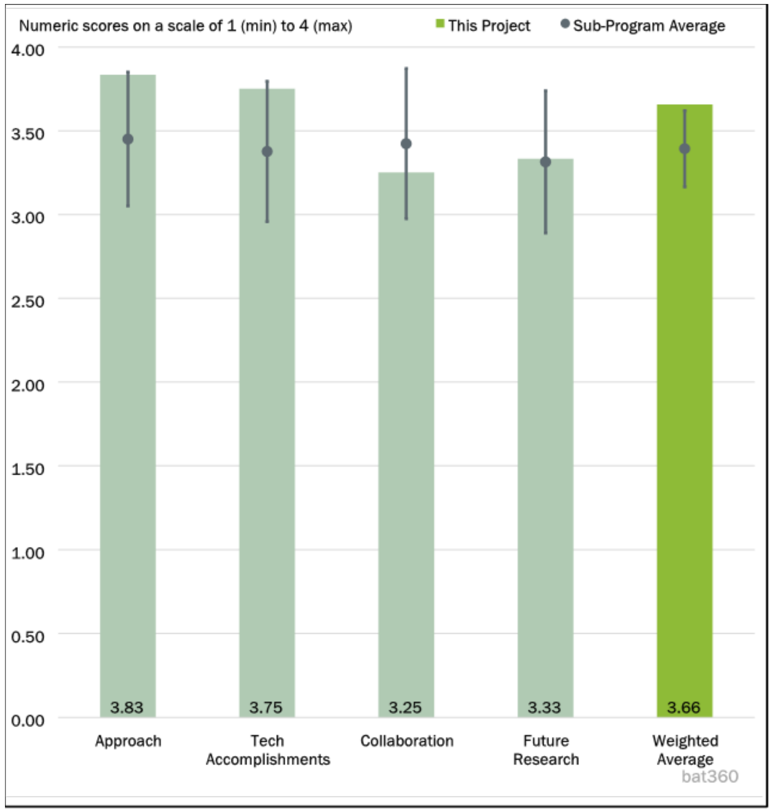

Figure 2-2 - Presentation Number: bat360 Presentation Title: Cathodes Beyond Lithium Nickel Manganese Cobalt Oxide (NMC) 811 Principal Investigator: Arumugam Manthiram, University of Texas at Austin

Presenter

Manthiram, University of Texas at Austin

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer commented as usual, Dr. Manthiram performs world-class research and generates very relevant and insightful findings. His titanium (Ti)- doped Ni rich cathode shows excellent performance and associated diagnostics are well performed and explained.

Reviewer 2

The reviewer said technical barriers are well addressed and designed, and the timeline reasonably planned. It clearly addresses less cobalt (Co) or no-Co cathodes with a good approach.

Reviewer 3

The reviewer commented there is significant technical progress made in this project that cannot be done without a successful approach and experimental plan that address the performance and safety barriers. The PI and team benchmarked the performance of Ti and aluminum (Al) doped Ni-rich cathodes (NATM) with respect to NMC and Ni-Co. The reviewer noted that NATM showed better performance in terms of capacity retention. The cycled cathodes were characterized using scanning electron microscope (SEM), time-of-flight secondary ion mass spectrometry (ToF-SIMs), DSC, and high-resolution transmission electron microscopy (HRTEM). The team tested different elelctrolytes with NMC and Ni-Co cathodes.

Reviewer 4

The reviewer said that the cathode is a critical bottleneck for improving energy density, and this project is very important and well-designed. The reviewer said the project includes approach fundamental understanding of the failure mechanism of high Ni cathodes, identifying the important factors which are responsible for the capacity fading, and controlling those factors to retain the capacity. The approach is rational and effective.

Reviewer 5

The reviewer detailed that this project seeks to understand the synthesis of high Ni cathode active material (CAM) without Co or Mn. They present a compelling NATM) formulation and seek to understand the effect that each dopant has on synthesis and performance. The reviewer noted that the Li metal work seems unrelated to the project Milestones, but it is great work nonetheless.

Reviewer 6

high-resolution transmission electron microscopy

The reviewer said the team addresses energy density barriers by advanced synthesis of high Ni, beyond NMC cathodes; incorporating a high salt concentration electrolyte; and a mechanism understanding from in whole cell characterizations. The approach from material synthesis, cell integration, to characterizations is well designed to achieve the goal of the project.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer remarked the team reported new compositions such as NC, NM, NATM, and NA . It seems NA seems to be a good optimized candidate out of all in terms of capacity (220) and retention (82%). The reviewer provided the following comments the team should consider.

The author also showed the exothermic peak for all except NA. Is the exothermic peak higher or lower and how much is it suppressed? The author also mentioned localized high concentration electrolyte (LHCE) reduces carbon dioxide (CO_2) generation dramatically with minimal effect on oxygen generation for LiFSi and not for $LiPF_6$-based localized saturated electrolyte (LSE). Then, what will be the approach for Ni-rich electrodes (NA and others) when cells exhibit better cycle life in $LiPF_6$-based LSE than in LP57 and LHCE?

Reviewer 2

The reviewer provided the following remarks.

- NATM cathodes showed a high temperature threshold and minimal heat release compared to other Ni-rich compositions. Ti and Al bonded to surface O atoms provided better thermal stability.
- STEM and TOF-SIMs results showed minimal cracking and better interfacial stability for NATM cathodes compared to other Ni-rich counterparts. The reviewer noted better cathode-electrolyte interface (CEI) stability.
- Regarding the pure Ni-rich cathode; the reviewer said $LiNiO_2$ showed much better stability and cycle life in LSE compared to LHCE and the baseline LP57.
- Differential Electrochemical mass spectroscopy (DEMS) results showed much lower CO_2 evolution when using LHCE for Ni-Co cathodes. The reviewer noted a favorable electrode-electrolyte interaction, and would be interested in similar experiments for LATM cathodes.
- Dual salt and LHCE electrolytes showed closed pack Li-morphology during plating at a respectable current density of 1 mA/cm^2 and forms mainly amorphous Li rather than crystalline. The reviewer

asked if the team has tested greater than 1 mA/cm^2 current density. What are the coulombic efficiency (CE) values reported for 1 mA/cm^2 plating and stripping?

Reviewer 3

The reviewer said very good progress, no issues.

Reviewer 4

The team synthesized a new cathode material NATM, which showed excellent battery performance and was explained by improved crack mitigation, reduced surface reactivity, and better thermal stability. The team also studied the outgassing and lithium plating behaviors of different cathodes and electrolytes. It was mentioned that all the cathode materials tested were uncoated. It is intriguing to know whether applying coating can further improve the cell performance. Is this in the future project plan?

Reviewer 5

Regarding NATM, the reviewer congratulates the University of Texas at Austin team on the development of their NATM CAM. The reviewer agrees with the authors that it is crucial to understand capacity fade mechanisms, and encourage the authors to study the mechanism for secondary particle cracking more closely. Cracking occurs when tensile stresses are generated on the surface of a secondary particle due to a decrease in volume of the particle surface. This may occur when the surface of the secondary particle is de-lithiated before the core of the secondary particle. The reviewer suggested the team look to silicon (Si) anodes for an analogy. The battery community knows that NCM materials shrink 3%-8 vol% upon de-lithiation, which is far less than Si, but still substantial. The reviewer said most of this volume change occurs during the H2 to H3 phase transition. For NMC333, it has been shown that Ti substitution will minimize the overall volume change from 4% to 3% (K.C. Kam et al., J. of the Electrochem. Soc., (2012), 159 A1383). The broadening of the H2 to H3 phase transition for NATM hints that such a mechanical explanation is likely as previously reported for NCA (G. W. Nam et al., ACS Energy Letters, (2019) 4, 2995-3001). The reviewer noted that reduced surface reactivity may also be a factor as the authors suggest. If the volume of the surface rock-salt phase is less than that of layered NATM then surface reactivity may explain the author's results as well. Elucidation of this question may yield a fundamental design principle to avoid secondary particle cracking.

Regarding outgassing, the reviewer said the authors demonstrated DEMS capability. The team should evaluate O_2 evolution of NATM using this method. Regarding Li-metal, the reviewer said the authors studied Li plating morphology and structure with different electrolytes. The reviewer said follow-up work should consider the effect of different CAMs to better understand crosstalk. How does TM dissolution, or lack thereof. affect Li-metal electrode cycling efficiency?

Reviewer 6

The reviewer said the team made significant progress during the past year. The team has developed a Co- and Mn-free high-Ni cathode and demonstrated good cycle and thermal stability. However, the loading of the cathode materials is relatively low (approximately 2mAh), which is far off from the targeted energy density of Battery500. The reviewer said when the loading is increased to more than 3.5 mAh, the cell performance could be different. The team should try higher loading, so it can provide direct performance data to the Battery500 team for better integrating with other teams' efforts.

The reviewer said the team claims amorphous Li can lead to improved cycle efficiency, and dual salt electrolyte and LHCE will reduce the formation of crystalline Li. The team might need more evidence and explanation.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said the team was actively collaborating with other institutes, including PNNL for cell evaluation, Stanford for fluorinated electrolytes, University of Washington for coating, Brookhaven National Laboratory and the Advanced Photon Source (APS) for synchrotron X-ray scattering.

Reviewer 2

The reviewer said the authors demonstrated excellent collaboration and coordination with other organizations. The thermal reactivity of NATM should be evaluated by BAT359.

Reviewer 3

The reviewer noted there is always an issue with scaling up cathode material production so the CAM can be used by other members of the Battery500 team. This reviewer had not noticed many of Dr. Manthiram's materials being used in cell builds at Pacific Northwest National Laboratory (PNNL) although the reviewer may have missed that.

Reviewer 4

The reviewer said collaboration within the project team is good, but no industry contributions are specified. This project seems to collaborate with national labs and other external entities, but new collaborative experiments are yet to be done with the team.

Reviewer 5

The collaboration across the Battery500 team is excellent, but the reviewer was not clear about the specifics of this project as far as collaborations. The reviewer would like to know if LSE and LHCE electrolytes were provided by partners.

Reviewer 6

The reviewer noted the team has pretty good collaboration across the Battery500 teams, which are mainly universities and national labs. Can the team also have more collaboration with industries for further evaluation based on industry requirements for EV applications, such as through USABC program. This would significantly accelerate the commercialization of those interesting cathode materials.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said the PI has a great path forward for the second year on all major technical barriers with desired performance metrics.

Reviewer 2

The reviewer said the team has clearly listed the future work to be conducted in the project. The accomplishment of the tasks will help achieve the overall project target in further improving energy density and cycling stability.

Reviewer 3

As mentioned, Dr. Manthiram's work is world class. The reviewer believed DOE's work on Ni-rich CAMs might be ready for de-emphasis. The reviewer explained that DOE has committed to pursuing earth abundant battery materials and this PI might be able to greatly aid in the development of sulfur (S), silicate, manganese (Mn)-rich layered, Mn phosphate, or other earth abundant CAMs.

Reviewer 4

The reviewer said the proposed project target 500 Whr/Kg may be possible with some of these cathodes. LATP coating (Yang) on separator in LiFSi, possible Nb coating (Dr. Stanley Whittingham) could be considered to improve the performance as a team work.

Reviewer 5

The reviewer said the author's proposed future work is reasonable, and encouraged DEMS and Li-metal morphology studies in conjunction with NATM.

Reviewer 6

The reviewer commented the future directions are rational. The team identified the most critical factors such as doping, but pushing everything to the limit could be high risk before solving the capacity fading for the current design. The reviewer also pointed out the safety of the new cathode materials needs to be addressed as well.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This project is highly relevant because improving the stability of CAMs is critical to achieving Battery500 goals.

Reviewer 2

The reviewer said yes, it supports overall VTO program objectives.

Reviewer 3

The reviewer remarked the project is critical and has close relevance with the VTO Battery program for high energy and low-cost battery technologies, as the new materials have more than 220 mAh/g capacity and are Co free.

Reviewer 4

The reviewer said the project supports the development of Ni-rich and low-Co cathodes and screens the relevant electrolyte systems for performance and safety. Overall, this project support development of Li-metal cells with high energy density and deep cycles.

Reviewer 5

The reviewer remarked the project is relevant to VTO objectives in batteries.

Reviewer 6

The reviewer said very relevant but, as mentioned above, it may be time to move towards earth abundant CAMs.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer saw no issues.

Reviewer 2

The reviewer said the proposed project milestones are achieved in a timely fashion.

Reviewer 3

The reviewer said the team is adequately funded to work on the proposed deliverables.

Reviewer 4

The reviewer cannot see a resource limitation encountered by the team.

Reviewer 5

The reviewer said resources of this project are sufficient.

Reviewer 6

The reviewer remarked yes; the Battery500 Consortium got the best research teams in the United States. Different teams have different expertise and strengths. The collaboration among the team would be a tremendous resource for the success.

Presentation Number: bat361
Presentation Title: Understanding and Improving Lithium Anode Stability
Principal Investigator: Yi Cui, Stanford University/SLAC National Accelerator University

Presenter

Yi Cui, Stanford University/SLAC National Accelerator University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

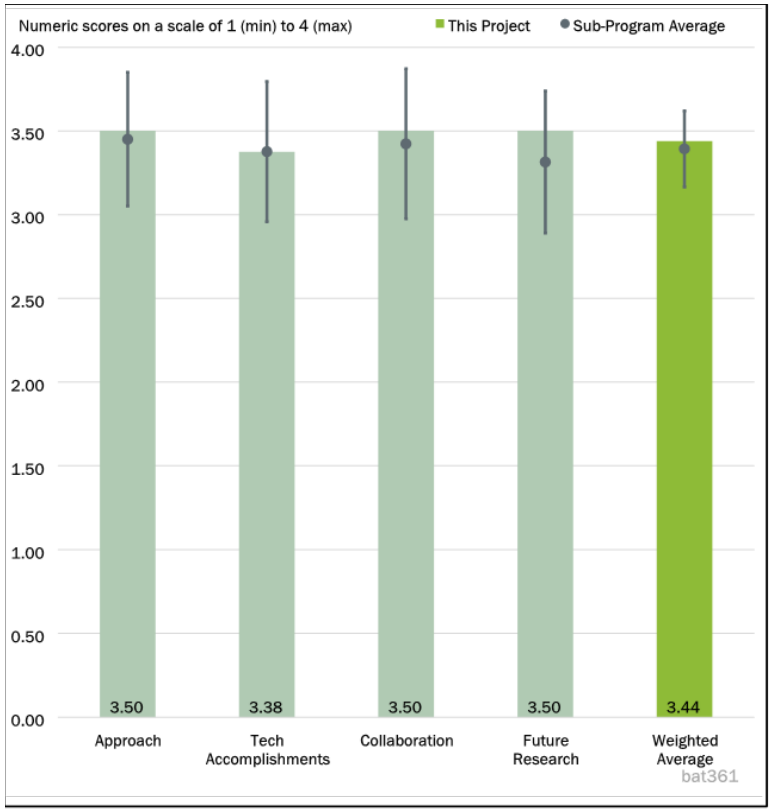

Figure 2-3 - Presentation Number: bat361 Presentation Title: Understanding and Improving Lithium Anode Stability Principal Investigator: Yi Cui, Stanford University/SLAC National Accelerator University

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer said the team has strong records in transmission electron microscopy (TEM) nanostructure characterization and has added operando X-ray diffraction (XRD) and transmission X-ray microscopy (TXM) to their tools. The team is attacking the most critical problems in the Li-metal battery with a 3D host composite.

Reviewer 2

The reviewer remarked as usual, the team is very creative in finding ways to address challenging issues. Here the team aims to reactivate dead Li-metal particles isolated from the anode by utilizing their dynamic polarization to the electric field and the existing voltage drop between the cathode and anode. The reviewer said the approach is novel, elegant, and consistent with the goal of Battery500 program. The reviewer believed the team deserves credit for their outside of box thinking and the thought-provoking approaches they often bring to the community.

Reviewer 3

The reviewer said the project is well designed. It aims to highlight how detached Li particles from the anode surface can move around inside the electrolyte upon applied potential across electrode. In fact, the team uncovered that the dead Li particles are not really dead materials, rather they can dance around. This phenomenon becomes important at high current rate batteries.

Reviewer 4

The reviewer remarked the project is effective in developing a robust Li-metal anode, which enables high cell specific energies of 500 Wh/kg. It does contribute to overcoming the barriers in the development of EV batteries that can meet DOE/USABC goals both in cost and performance by enhancing the specific energy and reducing the cost of EV batteries. This is part of a larger activity to develop various cell components for the 500 Wh/kg cells. The reviewer said the approach of developing a 3D Li anode architecture, new electrolytes that form stable solid-electrolyte interface (SEI), and new polymer coatings to further protect the Li anode is aimed at overcoming the technical barriers towards high specific energy and long life from the Li anode to be used in advanced high energy batteries. This year's effort has focused on understanding the formation of dead Li and retrieving part of the dead Li from the anode.

The reviewer cited as two weaknesses it would be more useful to emphasize the development of a Li anode (in conjunction with a new electrolyte) that will have reduced corrosion and minimize the occurrence of dead Li or dendrites, either with a 3D architecture or robust surface film, than to recover from the dendrite-induced effects; and the effort here seems to be a bit diffused briefly touching upon various aspects that may be interesting from academic perspective. But the Battery 500 program is more focused on advancing technology to fulfil the needs of future EVs. The reviewer said it would be greatly helpful if, and almost crucial, that a durable Li metal anode has emerged at the completion of this project to benefit the Battery 500 program

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer remarked the team has designed an experimental in situ set up to resemble the issue occurring inside battery system and provided sufficient evidence to support their hypothesis. The experimental results were further verified by simulation data.

Reviewer 2

The reviewer said excellent progress has been made in identifying various failure modes in the use of Li-metal anodes, using rational materials design and advanced characterization, which have been well summarized in several good publications. The project touched upon a new class of fluorinated electrolytes forming a stable SEI and new polymer coatings on the anode in previous years. The reviewer said this year's effort has focused on understanding the formation of dead Li and partly retrieving the dead Li using high charge/discharges currents. The method has been explained mechanistically in terms of field-induced migration of dendrites (dead Li) to get it connected to the anode and be reactivated. This is quite interesting and useful and will need to be validated in pouch cells.

The reviewer cited as a weakness the mechanism proposed here explains only one type of dead Li, i.e., located above the anode and formed from electronically disconnected dendrites. However, based on the reactivity and passivation characteristics of Li, it is conceivable that some of dead Li may be inside the anode, i.e., Li covered by thick SEI and buried inside the anode. In that scenario, the retrieval of dead Li may still be possible with high current discharge by the Li underneath the dead Li pushing the latter to the surface. Second, another possibility is the thermal effect from the high currents burning the dead dendrites. Finally, applying high charge/discharge currents may have adverse effects on the subsequent performance of cell. It is important to demonstrate the benefits of the proposed method in pouch cells for further validation to recover dead Li.

Reviewer 3

In the presentation, the team mainly introduced their work on the isolated Li-metal, published in 2021. This seems not directly related to the two milestones listed in Slide 4, which are studying Li nucleation mechanism using atomic force microscopy (AFM) and initiating the Li host with Cu substrate.

Reviewer 4

The reviewer remarked overall, good progress has been made on this project. The team is very productive in distributing their research results, with an impressive body of publications already appearing in high impact journals.

This reviewer's main concerns are related to the effectiveness of the approach in realistic cells. Several aspects are not clear and perhaps this can be worked into the next year's work. As there is no control on dead Li shape and orientation, the percentage of dead Li that can be activated is limited. The team demonstrated recovery of Li in Cu–Li cells with more than 100% CE, which suggests full activation of dead Li. The reviewer said considering the effectiveness depends on shape and orientation of the dead Li particles, it is unclear to this reviewer how it might be possible to get more than 100% CE.

More understanding in working mechanisms is needed. Do Li particles really migrate to the anode or do they just experience shape changes (one end gets fatter during charge and the other during discharge)? Does the shape of dead Li particles change over cycling? The reviewer remarked there was no experimental observation or evidence on actual particle migration and reattachment to the anode.

The reviewer said for sure the dead Li particles are covered with SEI products. What role does the SEI layer play and how do the different components in SEI affect the polarization, considering some are more isolating than others? In that sense, the nature of the electrolyte would be critical and it should be investigated in the study.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer remarked collaborations across the team in the Battery500 program and SLAC/Stanford University are outstanding and well executed.

Reviewer 2

The reviewer said while other groups did not actively participate in the design and testing of this work, the outcome is critically important for other groups working under this program.

Reviewer 3

The reviewer said the team has collaborated with researchers from universities and national labs. In the future, the team should indicate the affiliations of these researchers and also their contributions.

Reviewer 4

The reviewer noted that there are several on-going collaborations with the DOE Battery500 team members, i.e., Drs. Jun Liu, Jie Xiao, Jason Zhang, Wu Xu, Stanley Whittingham and especially several faculty members both from SLAC and Stanford University.

The reviewer cited as weaknesses that it is not clear what the specific activities of collaborations are with the Battery500 team. A more active collaboration to share the materials (3D anodes, electrolytes, Li coatings) from this project with the team or analyzing the anodes from the cycled cells from the team will be useful. Further, collaboration with any battery company manufacturer will be beneficial for a rapid validation of the method/materials.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said the team is aiming at the most critical problems in the Li-metal battery and the approaches are adequate.

Reviewer 2

The reviewer remarked that the proposed future study is well planned and involves further development of 3D Li metal anodes with stable interfacial modification and minimal volume change both globally and locally; electrolytes to form stable SEI assisted by cryoEM study; and polymer coating layer/electrolyte to facilitate the formation of stable SEI. Overall, the future plans are well aligned with the needs of Battery 500.

Reviewer 3

The reviewer said it has been discussed how to minimize the observed dancing effect of Li particles inside the electrolyte by modifying the electrolyte compositions. It is anticipated that the electrolyte composition can affect the conductivity of electrolyte and consequently the applied potential gradient to particles, and type of SEI layers on the anode surface, which could affect the detaching process of Li particles.

Reviewer 4

The reviewer said overall, the proposed future work is logical towards addressing the barriers in Li-metal based batteries. In this reviewer's opinion, the biggest challenges facing Li-metal cells is not necessarily CE or even cycle life. It is the safety issues relating to Li dendrite formation and propagation. Future research should tackle the safety issues, not only in this project but also the Battery500 program in general.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said the project, as part of the Battery500 program, will contribute greatly to accelerating vehicle electrification in the United States.

Reviewer 2

The reviewer commented the project supports the overall DOE objectives by identifying the life-limiting mechanisms of a Li anode for Battery500 chemistries, including the formation of dead Li, and mitigating these limitations through a combination of theoretical analysis, advanced characterization, and experimental verification. The R&D here is being carried out well by a capable research team with access to advanced analytical techniques with the primary objective of developing a robust Li anode that can be coupled with a high energy cathode (high Ni NMC or S cathode). Overall, the reviewer found this project is quite relevant to the DOE VTO Battery program's objectives and goals.

Reviewer 3

The reviewer said an effective use of Li-metal anode is critical in achieving the Battery500 goals. Current technology faces significant challenges in terms of low CE and poor cycling life of a Li-metal anode. By developing approaches to utilize dead Li, it can improve CE as well as safety, both of which are very relevant to the overall DOE objectives.

Reviewer 4

The reviewer noted the outcome of this project is important for the battery community if the team can find a better way to prevent or minimize dancing of the dead Li particles inside the electrolyte.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer remarked the resources for the overall Battery500 project are commensurate with the scope and are adequate to achieve the targeted milestones. Budget details for this specific project have not been provided.

Reviewer 2

The reviewer said the 5-year budget looks adequate for the targeted R&D activities of Battery500. Maybe it will be more informative to specify the budget for each subproject.

Reviewer 3

The reviewer remarked it is unclear how much funding this project receives so it is difficult to judge whether or not enough resources are available. But the overall Battery500 program has sufficient resources.

Reviewer 4

The reviewer said resources provided by VTO is outstanding.

Presentation Number: bat362
Presentation Title: High Capacity S Cathode Materials
Principal Investigator: Prashant Kumta, University of Pittsburgh

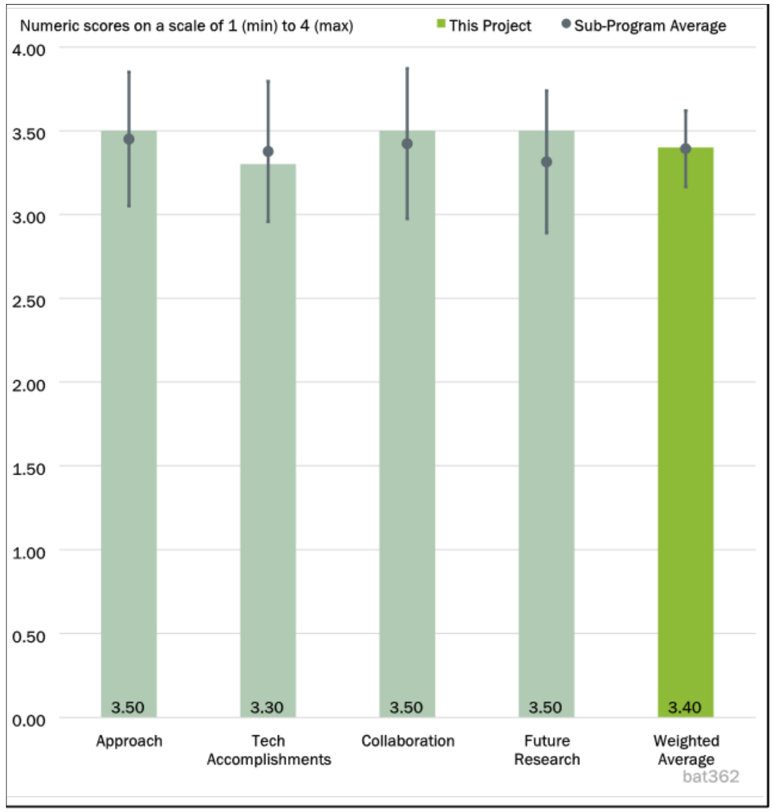

Figure 2-4 - Presentation Number: bat362 Presentation Title: High Capacity S Cathode Materials Principal Investigator: Prashant Kumta, University of Pittsburgh

Presenter

Prashant Kumta, University of Pittsburgh

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said Dr Kumta is using state of the art approaches to developing and testing S cathodes.

Reviewer 2

The reviewer said the project addresses the two key technical barriers for future EV batteries, which are low specific energy and high cost; improvements in these two categories are the goals and objectives of the Battery 500 program, to which the current project belongs. Lithium-sulfur (Li-S) chemistry is in principle well suited to meet for these performance targets, but it is deterred by few technical hurdles, the most important one being the polysulfide shuttle. This project is developing new S-capturing architectures, i.e., metal organic frameworks (MOFs) and porous and mesoporous ordered ceramics (POCs), in place of conventional hierarchical porous carbons. The reviewer noted that with these architectures, it may be possible to control the chemical affinity of S with different metal/ceramic frameworks. The initial results are reasonably promising though with low cathode capacity (only 400-500 mAh/g at the cathode level at C/3 (?)). In addition, the team is developing coated separators with polysulfide trapping additives (PTA). Functional electrocatalysts are being identified for enhancing the redox kinetics of lower sulfides. These cathode improvements are being combined with a Li alloy developed earlier by the PI. Cathodes with high S loadings are being developed to improve the cell specific energy, which is still well below the target. Overall, the approach looks reasonable and effective and contributes to overcoming the barriers of Li-S chemistry.

The reviewer cited as weaknesses even though the MOFs and POCs allow high S loadings, both the S utilization and the cathode (not S) specific capacity realized so far are considerably low to give any enhancement in specific energy. It is not clear to this reviewer how high specific energies of greater than 400 Wh/kg are possible with these architectures (i.e., if the required area-specific capacity mAh/cm^2 will be achievable). The reviewer also noted that a comparison with the porous carbon-S composites is needed to verify/demonstrate the benefits with the MOFs and POCs over the carbon hosts, and that Slide 6 does not apply to Li-S; need a chart that shows the targeted cathode capacity, E/S and negative electrode to positive electrode capacity ratio (N/P).

Reviewer 3

The reviewer noted that a LiS rechargeable battery is a very challenging chemistry to realize. However, there is a huge potential for this chemistry to be used for not only EVs, but also stationary energy storage and aviation energy storage. In particular, the S cathode materials desolation in the electrolyte during electrochemical process is a critical technical barrier to be solved. The reviewer said the proposed work is focused on preventing/managing polysulfides dissolution, the major technical barrier for Li-S battery chemistry. The project developed porous organometallic framework materials (POFM) and mesoporous ordered ceramic (MOC) structures with high surface area(100-1,000m^{2}g-1), control porositym and porous channels in size ranges of 0.2nm–100nm, and with channels available for infiltration of S and encapsulation of doped Li_2S within and around the POFM and MOC architectures. The reviewer pointed out this high surface area and high porosity approach to manage polysulfide dissolution has demonstrate initial success supported by earlier literature and research works. The project is well designed and timeline to achieve the program goal is reasonable.

Reviewer 4

The reviewer said the PI aimed to increase the rechargeable capacity of a S cathode. By synthesizing composite including organic composite S materials, the team demonstrated a capacity over 700 mAh/g S, and high S loading. Numerical calculation was applied for the better understanding of mechanism. The reviewer remarked the project is well allied with overall Batter500 objectives and the PI indeed engaged collaboration with other participant PIs in the project.

Reviewer 5

The reviewer said that though the technical barriers are addressed by the author, the following comments should be considered.

- How will the PTA inhomogeneity be controlled?
- S (low density) should be considered while achieving 500 Whr/Kg in full cell.
- How feasible is it to use MOC and POMC for practical use, what is the stability in the electrolytes used, how much of S is trapped (in terms of percentage), and could the sulfur shuttling should be completely stopped?

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer noted that this project just started in 2021. In collaboration with GM, the PI has selected a universal S baseline chemistry to evaluate and benchmark the performance of the POFM and MOC confined materials. The PI's lab has developed the POFM type 1 materials, and its initial performance has been evaluated and compared with the baseline chemistry. The reviewer said performance of POFM type 1 is similar to the baseline performance. Considering the project is in its initial stage of 13% in progress, the progress made by the PI team has been excellent.

Reviewer 2

The reviewer said progress has been in alliance with the project plan. The team made and tested the composite materials and polymeric electrolyte membranes. In the next AMR, we should expect the PI to demonstrate the integrated cell consisting of all components, e.g., composite electrode, polymeric membrane, and improved Li anode.

Reviewer 3

The reviewer remarked that progress is somewhat limited as this is a new project in the full Battery500 program. This reviewer would like to see the S projects (not just this one) ensure that their loading and porosity will result in a cell that is equal to today's Li ion in Wh/L. S cells struggle to match Li-ion in this critical metric. In addition, Dr. Kumta should continue to strive to reduce the electrolyte volume in his cells. The reviewer said that earlier modeling work identified 3ml/Ah as the highest electrolyte volume that could be used, and this project is currently at 8. In addition, there is always a concern when using scaffolding structures in the cathode, which introduce dead weight and volume.

Partially to address those "dead weight" concerns, this reviewer would encourage all S projects to report mAh/g (electrode) not mAh/g (sulfur). The latter is almost universally used in the battery community and it can be very misleading.

Reviewer 4

The reviewer said excellent progress has been made in the demonstration of laboratory-scale synthesis of modified complex framework material (CFM)-S hybrid composite and type 1 POFMs with high areal capacity of 3.5 mAh/cm^2 and decent cycle life of 80 cycles. Preliminary studies with the S cathodes using the framework materials (POFM) demonstrate the feasibility and show that it possible to incorporate high S loadings of 2-5 mg/cm^2. There is a possibility that these POFMs and similar MOCs can be optimized further with desired electronic conductivity and polysulfide trapping additives. The reviewer said separators coated with polysulfide trapping additives showed some improvement in cycle life, albeit with reduced capacity. The team is identifying new functional electrocatalysts (FECs) for enhancing the kinetics of lower sulfides. It will be interesting to see how well all these cathode and separator improvements and the Li alloy developed earlier perform synergistically in Li-S pouch cells.

The reviewer cited as weaknesses even though the initial results with these MOFC/POFMs look promising, they are far from what is needed to demonstrate high specific energy of Li-S, beyond the current Li-ion batteries. This requires high S loadings combined with better S confinements or PS trapping and improved S utilization and above all, low E/S. Not much is being done on the latter. The reviewer also noted that the GM baseline coin cell data does not look as encouraging, it may not be the most current data, and that the fluoroethylene carbonate (FEC) are being designed for Li_2S2-Li_2S reaction, which occur later (deep) in the discharge or early in charge. How about the rest of reactions involving higher polysulfides?

Reviewer 5

The reviewer said that technical progress is good compared to the project plan, and the stability of MOC and POMC must be examined while trapping S. The PTA coated on Celgard showed a stable capacity of 500 mAh/g for 80 cycles while the specific capacity of 700 mAh/g is shown without PTA coating. Is it because for the full cell in the second case or any other parameter to be considered?

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer noted how this is a Battery500 project, with broad collaboration with national labs, universities, and industry. In particular, the PI is working with GM on S battery baseline characterization and benchmarking, collaboration on materials characterization using state of the art synchrotron and electron microscopy facilities at national labs, and materials and phase evolution characterization using in situ XRD with Malvern Analytical. The reviewer noted that the PI's institution also has access to the NECST Laboratory–Energy Innovation Center in Pittsburgh for the development of modified coin cell testing and carbon nanoarchitectures, and development of pouch cell testing.

Reviewer 2

The reviewer said Battery 500 has been a well-managed team of PIs. The PI of this project was well integrated in the Batter500 teams. The PI collaborated with other PIs within the program and outside the program. His efforts contributed to overall objective of the large project.

Reviewer 3

The reviewer noted several ongoing collaborations with the DOE Battery500 team members, i.e., Brookhaven National Laboratory; Idaho National Laboratory; and SLAC/Stanford University on materials characterization using synchrotron and electron microscopy facilities. There is collaboration with Malvern Panalytical for Materials and phase evolution characterization using in-situ XRD. Blomgren Consulting Services Ltd. is another useful collaborator for electrolytes, additives, system performance. The reviewer noted internal collaborations within the University of Pittsburgh, i.e., with Dr. D. Krishnan Achary for solid-state nuclear magnetic resonance (MAS-NMR) characterization and Nanomaterials for Energy Conversion Storage Technology (NECST) Laboratory–Energy Innovation Center, for the development of modified coin cell testing and carbon nanoarchitectures and development of pouch cell testing. The reviewer noted that more active collaboration with GM and possibly an industrial partner (Li-S company) will be beneficial.

Reviewer 4

The reviewer cited no issues but there is little collaboration as this project is just getting started as a Battery500 project.

Reviewer 5

The reviewer said collaboration within the project team is good, but no industry contributions are specified. This project seems to collaborate with national labs and other external entities. But it is yet to be done.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said the proposed future study involving identification of POFM with optimized porosity and porous channels to incorporate high S loadings greater than 8mg/cm^2; type 2 and type 3 POFMs with cationic and anionic centers to trap polysulfides; mixed electronic/ionic conducting MOCs with functional electrocatalysts; and anode stabilizing agents to withstand PS attack are appropriate, effective, and will contribute to overcoming the barriers of Li-S chemistry and move towards Battery500 performance goals.

Reviewer 2

The reviewer noted that the project is centered on using POFMs ad MOCs to confine/manage polysulfides dissolution during the electrochemical operation of the S cathode electrode. The future work is focused on fully developing both the concept and materials choices to evaluate the effectiveness of polysulfides management by this class of materials. The reviewer noted that future work will also investigate the impact of the materials on the battery performance such as loading and low temperature performance.

Reviewer 3

The reviewer said S cathodes have the possibility to reach 500 Whkg and it depends on the approach for full cell considering the improvements with other team members.

Reviewer 4

The reviewer referenced prior comments on projected Wh/l and electrolyte volume

Reviewer 5

The reviewer commented future research was based on the current achievements. The PI proposed to optimize the physical properties of POFM and identity POFMs with centers of t rapping polysulfides. The reviewer said the PI should better understand the chemical nature of such entrapment.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said very relevant, S is Earth-abundant and very inexpensive.

Reviewer 2

The reviewer said the project supports the overall DOE objectives by addressing the performance deterrents of Li-S cells, which otherwise have the ability to meet Battery500 goals both in terms of specific energy and cost, more than any other technology being developed under Battery500. The reviewer said advancing this technology will be beneficial in several commercial as well as U.S. Department of Defense applications, beyond EVs (dual use). The R&D strategy adopted here is sufficiently novel, and albeit with a high risk has also high pay-off. The reviewer found that overall, this project is quite relevant to the DOE VTO Battery program's objectives and goals.

Reviewer 3

The reviewer commented this project is highly relevant to the battery storage subprogram, as the success of this project leads to significant reduction of both battery cost and the usage of critical materials.

Reviewer 4

The reviewer said yes. It supports overall VTO program objectives.

Reviewer 5

The reviewer remarked Li-S battery has been considered as one of the most promising chemistries to replace Li-ion batteries in transportations. The research on S cathodes is relevant to VTO objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said resources for the overall Battery500 project are commensurate with the scope and adequate to achieve the targeted milestones. Budget details for this specific project have not been provided.

Reviewer 2

The reviewer saw no issues with resources.

Reviewer 3

The reviewer remarked resource and project timelines are well aligned.

Reviewer 4

The reviewer said proposed project milestones are achieved in a timely fashion.

Reviewer 5

The reviewer remarked the PI and team of Battery500 have adequate resources for the proposed research.

Presentation Number: bat364
Presentation Title: Synergistic Effects of Electrode and Electrolyte Materials for High Energy Lithium Cells
Principal Investigator: Jihui Yang, University of Washington

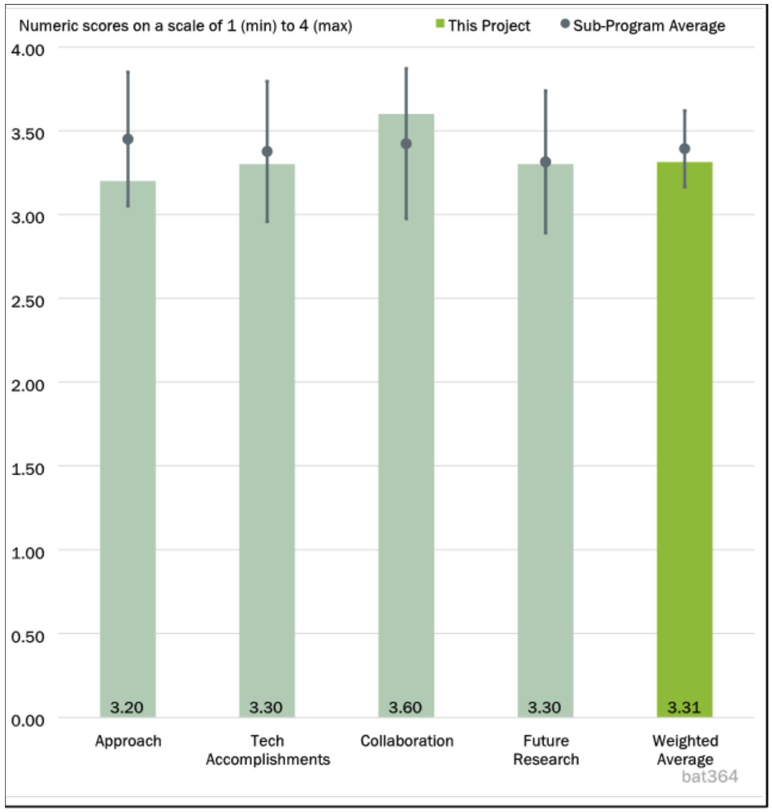

Figure 2-5 - Presentation Number: bat364 Presentation Title: Synergistic Effects of Electrode and Electrolyte Materials for High Energy Lithium Cells Principal Investigator: Jihui Yang, University of Washington

Presenter

Jihui Yang, University of Washington

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer remarked the PI and team are addressing key technical barriers that limit performance and stability of Li-metal cells. Enabling uniform Li-deposition and stripping using a three-dimensional (3-D) architectured current collector host, choice of electrolytes, and coatings. The reviewer said the combination of these improves the CE and capacity retention.

Reviewer 2

The reviewer found team did find the right problems to work on, including the anode structure, surface coating, and electrolytes; however, most approaches proposed have been reported in the literature. The team might need to come up with novel solution.

The reviewer said the 3D electrode architecture can reduce the local current density, but might compromise the volumetric energy density which is critical for EV applications. On the other hand, higher specific surface area could lead to more side reactions, leading to quicker capacity fading which the loading anode is well controlled.

Reviewer 3

The reviewer said that though the technical barriers are addressed by the author, the following comments should be considered.

Previously, the authors reported better results with Al-NMC811. The author should compare Al-NMC811 with LATP coating and LATP coating on a separator. The authors should address this result.

NMC811 in LiFSi seems to degrade too fast. The reviewer commented how does the LATP coating on a separator play a role when the NMC811 surface is in contact with a good amount of LiFSi. Also, the reviewer remarked address the mechanism in the case of Al-NMC811 with LATP coating and compare.

Reviewer 4

The reviewer said the University of Washington team is developing battery component integration techniques to improve the whole cell performance from coin cell to pouch cell. Even though the single component of batteries demonstrates excellent performance, without proper selection and integration of all cell components, the full battery performance can be underestimated.

Reviewer 5

The reviewer remarked the authors aim to improve the performance of Li metal electrodes via a 3D architecture and coatings on either the separator or electrode. The reviewer pointed out that the liquid electrolyte formulation and stack pressure are also critical factors to consider.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer noted that the team has made significant progress, including carbon host for a 3D electrode, the electrolyte for anodeless battery, and coating for separator. The team could show more details on the progress such as the cycle life for carbon host and copper host, which are critical for the community to see the technology can really improve the capacity retention or not.

Reviewer 2

The reviewer found that the authors showed improvement in capacity for the LATP coating. It is important to compare Al-NMC811 with LATP coating and LATP coating on separator and explain the mechanism.

Reviewer 3

The reviewer noted that the team tried a different carbon host and choice of electrolytes to determine the higher CE. Choice of electrolytes include carbonates, ethers, and LHCE. The team conducted similar experiments on copper host. The reviewer would like to understand how these results will affect the full cell performance in presence of a Ni-rich cathode. Are the carbon host presented part of the 3D architectured current collector? If so, more information needs to provided how they are integrated with a metal current collector or stand alone.

Reviewer 4

The reviewer remarked the team has studied coulombic efficiencies of cells made with various anode chemistry and structures as well as electrolytes, and found that the F5DEE electrolyte showed the highest CE and lowest overpotential. The reviewer said it is interesting to know that no matter what carbon host was used, the cell can all achieve greater than 99% CE with the use of LHCE electrolyte. In summary, the team stated that 3D CC is beneficial for the uniform deposition of Li-metal, although the reviewer cannot find the direct evidence from the team in the slides. What is the team’s next plan for 3D structured Li host? Is 3D anode design still an essential need giving the high CE achieved from the use of proper electrolytes?

Reviewer 5

Regarding host materials, the reviewer said the authors systematically evaluated Li-metal electrode CE as a function of host material and electrolyte. Cross sectional SEM shows dense Li deposits and greater than 99% CE when LHCE is used. The reviewer said that though not presented in the AMR slide deck, the paper associated with the carbon host work (Yao Liu et al., ACS Energy Letters, 2021, 6, 1550 - 1559) yields an interesting result. For NMC622/hard carbon full cells, "The capacity retention ratios were maintained at 80%, 57%, and 53% for N:P ratios of 1:1, 1:2, and 1:4, respectively, after 200 cycles." The reviewer noted that this result aligns with the findings of BAT369. Further work should investigate the mechanism for why N/P ratio = 1:1 yields the best capacity retention. Projections should be calculated to understand how the use of host materials affects cell energy density and cost.

Regarding separator coating, the reviewer said the authors present an impressive improvement in capacity retention by using an LATP-coated separator. The baseline Li/NMC811 cell presented here should be compared to those of other Battery500 projects. The authors should also investigate the mechanism for this improvement. The reviewer noted that by citing C.-Z. Zhao et al., Science Advances, 4, 11, 2018, the authors suggest that the LATP solid state electrolyte functions as an ion redistributor to smooth out Li-metal deposition. The reviewer is not convinced that the LATP coating participates in ionic transport. The authors should study the charge transfer impedance of the liquid electrolyte/LATP interface by employing the use LATP pellets. HF scavenging could be another possible mechanism in which case alumina could be used as a much cheaper separator coating material.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said the team has excellent collaboration with different institutions in the Battery500 Consortium. The expertise among the collaborators is complimentary, which is critical for the project to be successful.

Reviewer 2

The reviewer said the PI and team have demonstrated outstanding collaboration with other Battery500 teams. The reviewer noted that PNNL and Stanford provided electrolytes for the study, and the University of Texas (UT) Austin provided Ni-rich cathodes. Overall, a highly integrated project and deliverables.

Reviewer 3

The reviewer remarked the authors demonstrated excellent collaboration and coordination with other organizations.

Reviewer 4

The reviewer said collaboration within the project team is good, but no industry contributions are specified. This project seems to collaborate with national labs and other external entities. But it is yet to be done. The reviewer said it might be good to work with Nb coated NMC811 (Stan) combining LATP coating.

Reviewer 5

The reviewer commented the team is in close collaboration with PNNL on separator coating, UT-Austin and Binghamton University on Ni-rich NMC synthesis and characterization, Stanford on new electrolyte formulation, and INL on pouch cell test.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said proposed future work makes sense.

Reviewer 2

The reviewer remarked the team has clearly defined the future work based on the current findings. For the 3D architecture anode design, relevant length scales might be considered to avoid the reduction of energy density due to unnecessary increase of anode thickness.

Reviewer 3

The reviewer said it is proposed that Li host behavior without depletion of Li-metal at discharge state will be investigated. It might be possible to reduce depletion of Li-metal and may not be possible without depletion.

Reviewer 4

The reviewer said that more specific details need to be provided beyond a high level. For example, what kind of new electrolytes and host (beyond what is presented here). The reviewer said specific targets such as achievable current densities and cycle number need to be projected to measure success against existing base line results. For example- "Identify proper experimental parameters- E/S ratio". What would be the new E/S ratio the team is targeting to have. The reviewer said that Phase-1 of Battery500 has already provided some base line performance and the goal should be compare and move beyond what had been accomplished.

Reviewer 5

The reviewer said the proposed future research is too general. It should show some specific directions which address the barriers for the project.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said yes, it is relevant to the target for the Battery500 Consortium.

Reviewer 2

The reviewer said yes, it supports overall VTO program objectives.

Reviewer 3

The reviewer remarked the project is part of the Battery500 goal of achieving a cell level target of 500 Wh/Kg for Li-metal and various approaches to eliminate excess inactive materials and improve cell performance by using next generation electrolytes and coating strategies. One of the goals is to deliver the results in a pouch cell format ready for industry to evaluate and follow up.

Reviewer 4

The reviewer commented the project supports the VTO battery objectives in high energy density and long cycle life by developing better interfaces and anode architectures.

Reviewer 5

The reviewer noted that this project dovetails with work on advanced electrolyte formulations.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said the team has strong collaborations with other Battery500 teams and sufficient resources in conducting the battery performance evaluation task and interface modification task.

Reviewer 2

The reviewer said the resources of this project are sufficient.

Reviewer 3

The reviewer remarked the proposed project milestones are achieved in a timely fashion.

Reviewer 4

The reviewer noted that this is a consortium project—all PIs and their labs together deliver the milestones through collaboration.

Reviewer 5

The reviewer commented yes, the Battery500 Consortium has the best research teams in the United States and can provide sufficient resources to the success of this project.

Presentation Number: bat365
Presentation Title: Stabilizing Lithium Metal Anodes by Interfacial Layer and New Electrolytes
Principal Investigator: Zhenan Bao, Stanford University/SLAC National Accelerator University

Presenter

Zhenan Bao, Stanford University/SLAC National Accelerator University

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

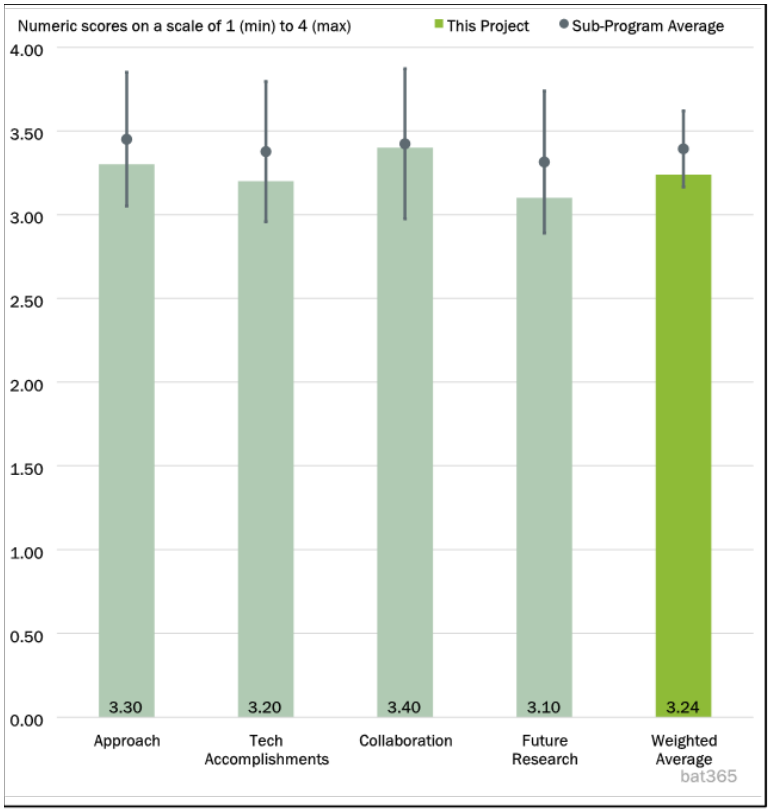

Figure 2-6 - Presentation Number: bat365 Presentation Title: Stabilizing Lithium Metal Anodes by Interfacial Layer and New Electrolytes Principal Investigator: Zhenan Bao, Stanford University/SLAC National Accelerator University

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer detailed that the proposed work concerns high CE electrolytes and coatings to stabilize a Li-metal anode. The work encompasses synthesis, cell assembly and theory. The reviewer is particularly impressed by the effort to use theory to design the optimal solvation structure for the applications. The proposed molecular structures on Slide 6 are interesting as they include both oxygen and fluorine atoms to address the trade-offs between ion transport and electrochemical stability. The reviewer said the PIs have an excellent track record of publications in high profile journals. The project is well-designed and well planned.

Reviewer 2

The reviewer said very good approaches being evaluated for enabling Li metal.

Reviewer 3

The reviewer said the PIs present results showing an anti-correlation between Li-ion solvation in an electrolyte and Li-metal stripping/plating reversibility. To do so, the team systematically changed the electrolyte solvating power through solvent/non-solvent mixtures, and selective fluorination of small molecular ethers. The reviewer noted the team’s electrochemical analysis clearly indicates the important relationship between poorly solvating electrolytes and improved Li-metal reversibility and plating uniformity.

Reviewer 4

The reviewer said it appears that the team has an excellent division of labor, and is using expertise and personnel time appropriately across the different sites. It appears that the milestones have mostly been satisfied on time and the team has achieved progress toward more stable batteries with higher energy density.

Reviewer 5

The reviewer noted that according to Slide 6, the PIs on this task have four different approaches for dealing with the CE. The reviewer remarked when the team talks about CE, it is hard to tell if the team is talking about the cell's CE or the rate of side reactions on the Li. Approach 1, make a new conductive electrolyte that is stable with carbon-fluorine (C-F) and C-O chemistry (the reviewer does not believe this will stand up to Li's reduction potential.) The reviewer said that Approach 2 is to develop a new co-solvent that is stable to Li (easier said than done). Approach 3, use a localized high concentration electrolyte, which is an electrolyte with a reductively stable salt like LiFSI, another solvent that is miscible with the main solvent but has a low solubility for the salt (this means that the overall salt solubility will decrease but the local solvation of the salt will be primarily with the main solvent). The reviewer was not sure why this will work if it has already been shown that the main solvent is not stable. (Is LiFSI 100% stable against Li?). Approach 4 is an inorganic-SEI and electromechanical stabilization stiffened electric double layer. Overall, it is good to come up with an electrolyte that is overall more stable to reduction than is the standard electrolyte but to fix the lithium passivation problem will require more, like a fully passivating film made either in situ or ex situ. No real discussion of the SEI that will be formed if any of these electrolytes is not stable, except maybe the last Approach.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer said technical accomplishments include: a systematic study on Li-ion solvating power of dioxolane mixtures with various co-solvents and their impact on Li plating, the development of partially fluorinated ethers and a study on their role in influencing Li metal plating reversibility, and an optimal electrolyte that promotes 'quick activation' of high CE Li metal cycling. Given the level of funding, this is good progress for the Stanford Battery500 team.

Reviewer 2

The reviewer said the PIs have studied mixtures of solvents (nonfluorinated) to study the interrelationship between solvation structure, studied by NMR, cycling behavior, studied in electrochemical cells, and electrodeposited Li morphology by SEM (Slide 7). The reviewer noted that the main conclusion is lower solvation of Li+ results in lower overpotentials and more planar deposition. This knowledge is important for enabling Li-metal anodes. The reviewer was impressed by the systematic study of ionic conductivity as a function of chain length shown in Slide 9. Perhaps the PIs may want to study the effect of chain length on other ion transport properties, relevant to battery operation. The reviewer pointed out the effort to understand CE as a function of molecular composition in Slide 12 is also noteworthy. The PIs have made excellent technical progress. Some indication of how theory is being incorporated into molecular design would have been good to see.

Reviewer 3

The reviewer said very good progress reported, and the reviewer would encourage the PIs to adhere to standards discussed elsewhere, such as a maximum electrolyte volume of 3ml/Ah. The reviewer believed this team is using 8, which makes performance look much better than it would at 3 but also hurts cell Wh/kg due to the extra non active material weight.

Reviewer 4

The reviewer said the new electrolyte materials developed and presented are enhancing CE and longevity of batteries at the pouch cell level, which is exciting. Below are specific technical questions related to the PI's presentation of results at the AMR. (These are repeated below in the Question 8 section.)

The reviewer said regarding the idea of electrolyte formulations with varying "solvation strength" for Li+: The PI mentioned that changes to the electrolyte solvents can cause the anion to solvate Li^+ more or less strongly. Can one also think of this as the solvent solvating anions better than it solvates Li^+? Furthermore, C-F bonds in solvent molecules are quadrupolar and assumedly should associate better with C-F bonds in FSI than C-H bonds in other species. The reviewer remarked might you use another related concept that is the use of momentarily associated ion-ion clusters that are locally complex structurally? From the answer to the related question during the talk, it sounds like this team is thinking about some these perspectives.

Regarding solvation and ^7Li NMR chemical shift trends: What does this team see with anion shifts (19F) and/or solvent shifts (1H or 19F)? Note also that FSI and PF6 have only one 19F shift, but you also have 13C for FSI and 31P for PF6.

The reviewer remarked would it be instructive to compare these DME-based electrolytes with the perfluoropolyether (PFPE) systems studied several years ago (Balsara and DeSimone)?

Reviewer 5

The reviewer said the first TA is in regards to mixing different solvents with DOL (considered a good solvent for limited dendrite growth.) They explain that NMR can determine if the solvation of Li increases or decreases with the addition of solvents to DOL. DOL is a poor solvent in that the over potential for Li deposition increases with cycling. The reviewer said the presenters believe that reduced solvation reduces the over potential for Li deposition and provide some data to that effect. DOL plus hexane in equal parts shows the lowest Li solvation of the samples tested, the lowest overpotential for Li deposition and the best, long term, steady cycleability. The reviewer said the team believes part of this is because the deposited Li is more two dimensional when deposited from DOL+Hex.

The next TA is results based on an H-cell. The reviewer suggests that the team put a baseline electrolyte in one half (DOL?) and the standard plus a diluent in the other half of the H-cell and measured the voltage of the cell as a measure of whether the Li-ions are more or less solvated. This voltage is a measure of both the thermodynamic difference and the transport properties through the barrier between the two cells. The reviewer said the team also show a plot of CE versus the voltage in their H-cell—the reviewer was unclear how the team got the CE data. Without knowing where the CE data came from, it is hard to tell what this means. The reviewer noted the team shows conductivity of a solvent with three blocks—the one in the middle has lots of C-F bonds and the ones on the outside are polyethylene oxide (PEO) type strands. The team show that the more PEO type, the better the conductivity but the lower the oxidative stability. The reviewer suggests it is not clear why the oxidative stability is of note for protecting Li.

The reviewer remarked that the team then shows that the best overall performing cells are with a solvent that is a short piece of PEO with fluorinated end groups and say this is the best combination of conductivity, CE, Li, CE, overpotential, and oxidative stability. The reviewer was unsure how the team is measuring the lithium CE.

The next slide shows the results of lithium stripping and plating. For 1 mAh/cm^2 of cycled Li the team gets an efficiency as high as 99.9% but for the 5 mAh/cm^2 cell, the team gets 99.5%. If the cell is to cycle 1000 times, 0.005 times a thousand is 5 which means they will lose 5 times the amount of the minimum amount of Li needed before they run out of Li in the cell. For a 5 mAh/cm^2 cell, that is 5 microns/mAh x 25 = 125 microns of Li - way too much. The reviewer noted that the team also shows full cell cycling data that falls roughly into two groups: one group is around 150 cycles and the other between 200 and 250 cycles. This would not be considered excellent. The reviewer said these projects could use more interaction among the participants. It comes off as 4 projects under one banner.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said Battery500 is a strong team (PNNL, Stanford, Binghamton, etc.), with clear synergies between team members. Overall, the coordination between team members appears excellent and quite collaborative.

Reviewer 2

The reviewer said that Slides 5 and 13 (which are similar) show the connection between the team and other members of the Battery500 and U.S.-German teams. Evidence for these collaborations is provided clearly in the publication list on Slide 20.

Reviewer 3

The reviewer said good interaction with other team members.

Reviewer 4

The reviewer remarked that it appears that the collaborations among the team members at multiple universities (Stanford, UT-Austin, University of California-San Diego (UCSD), University of Washington, and SUNY Binghamton) and national laboratories (PNNL, SLAC) are fruitful and solidly operating. The reviewer might expect more attempt to understand (and present) how the electrolyte stability and conductivity are related, and how this relates to ion clustering or local chemical environment. This is a challenging long-term project, and so developing understanding should perhaps feed into success more efficiently.

Reviewer 5

The reviewer said Slide 13 indicates that SLAC/Stanford can work in isolation on developing electrolytes and can reach out for other parts of the battery when needed. This task appears as four separate projects with no meaningful collaboration.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said the proposed work slide (Slide 14) is an accurate description of the program, where it stands, and what the PIs are trying to control with the ultimate goal of enabling high energy density Li-metal batteries.

Reviewer 2

The reviewer remarked good future plans.

Reviewer 3

The reviewer said proposed future research addresses the need for enhanced mitigation of electrochemical breakdown of battery components during use, notably electrolytes. From the presentation, the specifics of new directions are not exceedingly clear.

The reviewer provided specific technical questions related to the PI's presentation of results at the AMR, which might be useful for future research. Regarding the idea of electrolyte formulations with varying "solvation strength" for Li+: The PI mentioned that changes to the electrolyte solvents can cause the anion to solvate Li+ more or less strongly. The reviewer asked can one also think of this as the solvent solvating anions better than it solvates Li+? Furthermore, C-F bonds in solvent molecules are quadrupolar and assumedly should associate better with C-F bonds in FSI than C-H bonds in other species. Might the PI use another related concept that is the use of momentarily associated ion-ion clusters that are locally complex structurally? From the answer to the related question during the talk, it sounds like this team is thinking about some these perspectives.

Regarding solvation and 7 Li NMR chemical shift trends: What does this team see with anion shifts (19F) and/or solvent shifts (1H or 19F)? Note also that FSI and PF6 have only one 19F shift, but you also have 13C for FSI and 31P for PF6.

The reviewer asked would it be instructive to compare these DME-based electrolytes with the perfluoropolyether (PFPE) systems studied several years ago (Balsara and DeSimone)?

Reviewer 4

The proposed future research seems reasonable, although somewhat vague—the future work slide provides rather high-level research directions with no clear specific plans, although the reviewer is sure the plan entails an extension of the current year's technical accomplishments.

Reviewer 5

The reviewer said future work needs to be carefully reconsidered. The first thing the team conveys is the need to understand the balance between stability and solvation. But the investigators already know that oxygen in their solvent promotes Li solvation and fluorine in their solvent promotes electrochemical stability. The team could use more collaboration to think through this complicated problem.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This project strongly supports VTO objectives, as understood by this reviewer. This project is producing new electrolyte and interfacial layer materials that are improving the efficiency and longevity of Li-based batteries.

Reviewer 2

The reviewer pointed out that stabilizing and enabling Li-metal is critical.

Reviewer 3

The reviewer said the project is relevant to two subprograms—batteries and materials. The PIs present a systematic approach for resolving the conflicting needs of electrochemical stability and rapid ion transport.

Reviewer 4

The reviewer remarked the project supports the VTO subprogram objectives because getting to pure Li anodes leads to a major advance in energy density. This, as seen, is an extremely challenging objective, especially with a liquid electrolyte.

Reviewer 5

The reviewer said yes; if enabled, reversible Li-metal electrodes could provide an important step forward in Li battery energy density. This work aims to understand how to control Li metal deposition in liquid electrolytes.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said resources are sufficient to meet milestones in a timely fashion. The PIs have an excellent track-record of publishing their findings in the literature.

Reviewer 2

The reviewer remarked the team has access to world-class facilities, tools, and laboratory support personnel. The funding level and collaborative team appears to be quite sufficient to accomplish the stated goals. It is difficult to say $75 million from DOE is appropriate for this entire team, because this reviewer was tasked with only assessing one PI (Bao) in this huge multi-PI and multi-institution effort.

Reviewer 3

The reviewer commented the level of funding is sufficient given the size of the team and the problems facing Li metal electrodes.

Reviewer 4

The reviewer saw no issues. But, as with all other Battery500 projects, it is not possible to answer this question as no PI reported the funding to their specific project. This is not a comment directed at this project, but rather at all Battery500 projects.

Reviewer 5

The reviewer remarked the PIs do not list the amount of resources used in this project. The reviewer noted that instead of listing generally how much each of the projects in this task cost, which the team could have done on the second slide under budget, the team listed the entire budget of the program. Therefore, this reviewer must assume that $75 million is being spent on this effort, which is way too much.

Presentation Number: bat366
Presentation Title: Manufacturing and Validation of Lithium Pouch Cells
Principal Investigator: Mei Cai, General Motors

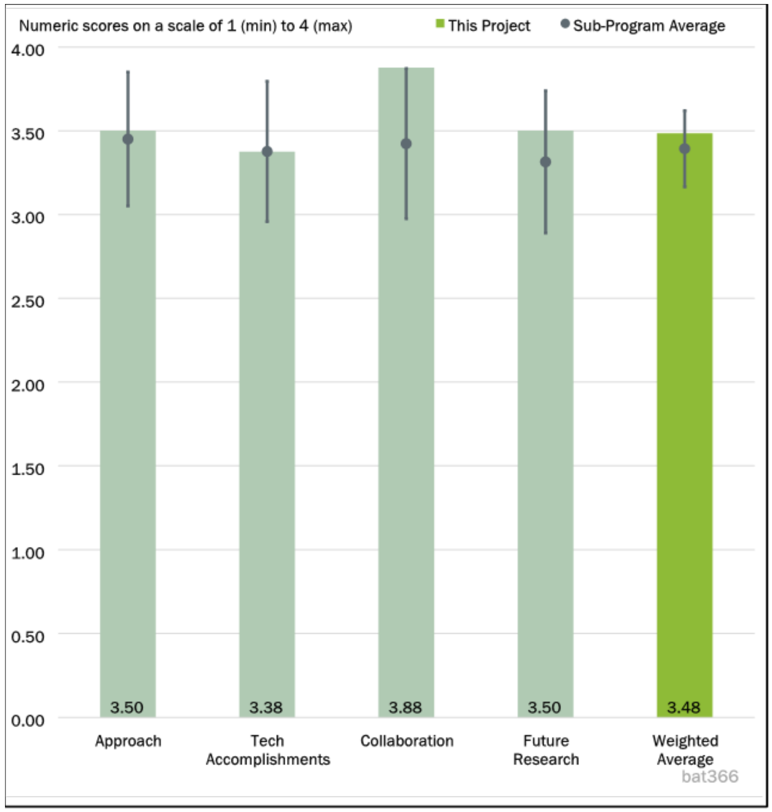

Figure 2-7 - Presentation Number: bat366 Presentation Title: Manufacturing and Validation of Lithium Pouch Cells Principal Investigator: Mei Cai, General Motors

Presenter

Mei Cai, General Motors

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer said the team has built and commissioned facilities for continuous fabrication of Li-S, and made and tested the pouch cells. Dual function electrolyte has been designed and tested for the high performance of Li-S batteries. The reviewer noted that although the stability is still low, the team should be able to overcome the technical barriers by incorporating the technical advances from the collaborating team members in next stage.

Reviewer 2

The reviewer said the team proposed well-known approaches for their Li-S cell, polymer electrolyte to protect Li-metal and liquid electrolyte for S cathode, with coated separator to trap polysulfide.

Reviewer 3

The reviewer remarked the project is well planned and designed to meet the challenge of doubling the energy density of current commercial EV Li-ion cells. The technical achievements reported indicated that the timeline is reasonably well-planned.

Reviewer 4

The reviewer said that the team demonstrated Li-S pouch cell performance using dual electrolyte approach—solid electrolyte coating on Li-metal and liquid for S. The reviewer noted a dedicated coating line for S electrode fabrication and scale-up—single and double side coating of C/S electrodes. The team developed a coating on separators for trapping polysulfides

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer pointed out that the dual-phase electrolyte proves to work for the stability of the anode. Implementing the polysulfide trapping layer enhanced the cyclability of Li-S batteries. The team accomplished the continuous fabrication of Li-S cathode process with normal and high S loading with reasonable cycling stability of 100 times at 0.1C.

Reviewer 2

The reviewer said the team has made significant progress and is on track of developing a high energy Li-S pouch cell. In the past, many researchers have been working on developing Li metal and Li/S cell technologies but have to give up because they cannot meet the challenge of improving the energy density and cycle life of the Li metal anode system. The GM team has made Excellent progress in increasing the energy density and is now working toward improving the cycling of Li metal anode system.

Reviewer 3

The reviewer said the team demonstrated good cycle life in both medium ($4mAh/cm^2$) and high loading ($6mAh/cm^2$), albeit very excessive Li (500um) and high E/S ratio of 8. The reviewer was not clear how the CE can be greater than 1 when the discharge capacity is less than the charge capacity (Slide 11). The team, and any other Li-S performers, should report the self-discharge of their cells at 100% state of charge at RT to track progress on polysulfide mitigation. The reviewer said that CE alone is not specific enough to track the polysulfide issue because CE is affected by Li-metal cycling.

Reviewer 4

The reviewer remarked the polymer coated Li-metal shows stable plating and striping compared to uncoated ones at the state current density. The reviewer would like to know if 1000 hrs. is arbitrary or based on some baseline performance metrics.

The reviewer noted that the metal oxide/C coating on separators traps polysuflides and improves performance but still there is a loss of Li-inventory. More mechanistic investigation is needed to conclude that coating separator improves sulfur utilization. The reviewer also noted that reported performance for Li-S cells for two S loadings with described protocol is an excellent progress. What is justification is there for 70% porosity? Is it optimal? How does it compromise with the overall energy density?

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer remarked there is outstanding collaboration and coordination across the Battery500 teams. Each Battery500 team has been using their own expertise to develop solution for a specific challenge that help the GM team integrate the developed solutions into the high-energy Li-metal anode pouch cell.

Reviewer 2

The reviewer said the team works in close collaboration with other team members by incorporating the technical advances from cathode, anode, electrolyte as well as fabrication involving the UCSD, University of Pittsburgh, Penn State University, PNNL/University of Washington, and General Motors.

Reviewer 3

The reviewer said the team is very collaborative with other Battery500 partners with each team/institution having specific goal provided for S electrode, electrolyte, or developing diagnostic tools.

Reviewer 4

The reviewer remarked GM partnered with four national labs and several well-known universities working on battery technologies.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer commented the team will continue to optimize the Li-S fabrication by collaborating with other team members, and fabricate the large pouch cell of 5Ah. With the facilities available, the reviewer expects more exciting results.

Reviewer 2

The reviewer said the proposed future research is outstanding and clearly defined to mitigate and develop solutions for the current challenges of preventing Li dendrite formation and polysulfides cross contamination. The proposed future research program has a great potential of reaching the goal of a stable Li cell with energy density of 500 Wh/kg.

Reviewer 3

The reviewer remarked scaling up Li-metal coating and electrode fabrication is an important step forward. Team needs to provide go/no-go metrics. The reviewer pointed out that carbon/sulfur electrodes have been tried before—what is unique about the S electrode architecture that has the right loading and performance targets.

Reviewer 4

The reviewer said future work should focus on demonstrating cycle life with significantly reduced excess Li and reduced E/S ratio, and also self-discharge rate comparable to transition metal oxide cathodes.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer commented the project is extremely relevant for the United States to reach the goal of carbon-free clean energy. It is practically impossible to reach that goal without the success of this project.

Reviewer 2

The reviewer said the project is relevant to materials development, batteries production, and also EVs.

Reviewer 3

The reviewer said proposed work met VTO program objectives.

Reviewer 4

The reviewer said relevance is adequate. Having an active industry partner helps to support deliverables and commercialization.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said with the fabrication facilities available, the allocated $15 million for running the tests will be sufficient for manpower, consumables, and characterization tests.

Reviewer 2

The reviewer said resources are adequate.

Reviewer 3

The reviewer said the long-term commitment and funding resources that DOE provides to this project are the key enabler for the Battery500 team to be successful. The resources are sufficient for the project to achieve the stated milestones on time.

Reviewer 4

The reviewer said sufficiently large funding for the large team.

Presentation Number: bat367
Presentation Title: Multiscale Characterization Studies of Lithium Metal Batteries
Principal Investigator: Peter Khalifah, Brookhaven National Laboratory

Presenter

Peter Khalifah, BNL

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

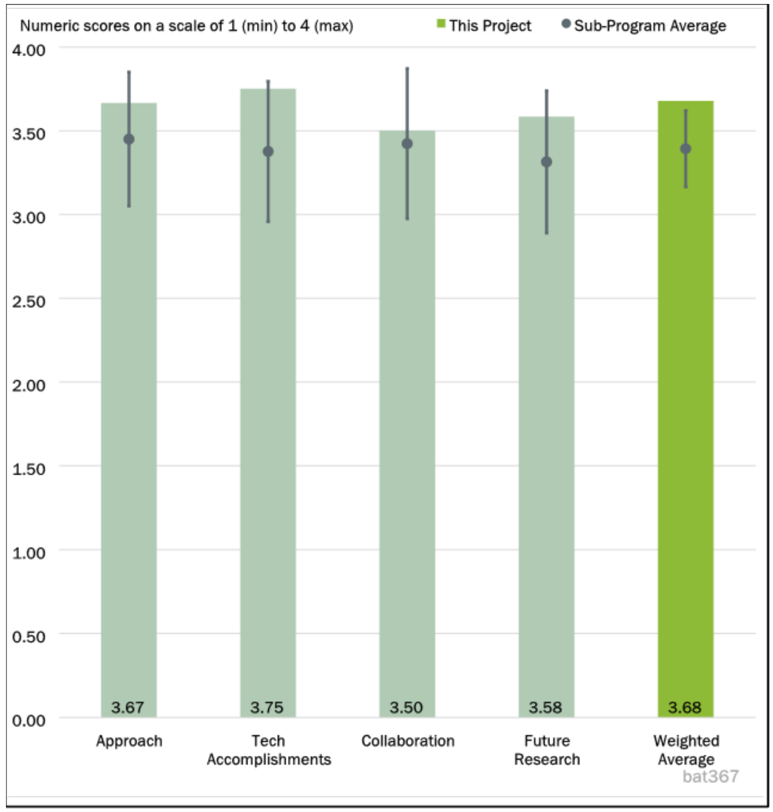

Figure 2-8 - Presentation Number: bat367 Presentation Title: Multiscale Characterization Studies of Lithium Metal Batteries Principal Investigator: Peter Khalifah, Brookhaven National Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer said the project is well designed with very effective approaches. The combination of synchrotron techniques and the density functional theory (DFT) calculation worked well in understanding and solving problems in Li-metal batteries. The reviewer noted the team has very strong records in applying synchrotron structure/morphology characterization in battery study.

Reviewer 2

The reviewer remarked synchrotron measurements are being integrated with modeling. Going from single atoms to full pouch cell—these are important and are not always done.

Reviewer 3

The reviewer noted the team utilized X-ray synchrotron XRD to study Li-deposition on copper in a pouch cell (anode free), and used spectroscopic tools to investigate the role of additives towards improving the performance of Li-NMC 811 cells.

Reviewer 4

The reviewer remarked the team has developed a very unique capability to quantify the dead Li with good spatial and temporal resolution, which can provide a critical fundamental understanding of the failure mechanism of Li metal electrolyte and guidance for how to optimize the electrode and electrolyte design.

Reviewer 5

The reviewer noted that though the technical barriers are addressed by the author, the following comments should be considered.

The reviewer said the authors must show the baseline electrolyte. It seems $LiPF_6$. The authors claim adding $LiPO_2F_2$ greatly improves cycling of Li/NMC811 cells at high voltage. It is good. However, Stan showed Nb coating on NMC811 provided 220 mAh/g in LiFSi. How will the team collaborate when they use two different electrolytes?

Reviewer 6

The reviewer commented the team uses synchrotron facilities to run operando or ex situ characterizations on pouch cells, targeting understanding the Li deposition/stripping behaviors, sulfurized polyacrylonitrile (SPAN) intermediates, and the effects of electrolyte additives. The approach also has a portion of modeling and calculation efforts stated in the project.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer said the team has established the excellent capability to characterize the Li plating and stripping, and understand the structural and bonding changes in SPAN. Most importantly, the team was able to get deep understanding of the enhanced the performance of electrolyte additives with the novel approaches.

Reviewer 2

The reviewer said the team has made impressive progress on the project, including the TXM studies on CEI interphase protection, and X-ray pair distribution function (PDF) studies on SPAN cathode. The team has recently made excellent progress in the characterization of Li metal plating stripping and the mechanism studies in $LiPO_2F_2$ addition.

Reviewer 3

The reviewer said direct quantification of Li-metal in a cycling pouch cell is a difficult experiment. The team succeeded in getting very useful information about the Li-metal distribution with a novel experimental design and the high intensity of synchrotron X-ray beams. This will allow more thorough studies on the Li-metal deposit/depletion mechanism in electrochemical cycles. The reviewer noted the Li-metal scattering is rather weak even with the high-intensity X-rays, which may cause difficulties in detecting Li signals at the beginning of the Li deposit, where the thin Li layer has not formed a crystalline form. The reviewer said the team may consider combining the TXM technique to investigate the oxidation state of the NMC cathodes to compare the spatial map of Ni2+/Ni3+ distribution and the Li-metal distribution.

Ex-situ PDF analysis on SPAN at different state of charge provides interesting insights into the cathode and the new UCSD electrolyte. Adding the proper amount of lithium difluorophosphate in the electrolyte greatly enhanced the cycling performance of the high-nickel cathode, which represents a great breakthrough in high nickel cathode Li-metal battery. The team reports their results in trying to understand the origin of the cycling enhancement with DFT calculation and spectroscopic studies.

Reviewer 4

The reviewer noted that the addition of $LiPO_2F_2$ greatly improves cycling of Li/NMC811 cells at high voltage. It is important to show the baseline electrolyte and compare $LiPF_6$ and LiFSi.

Reviewer 5

Regarding the spatial resolution of Li-metal, the reviewer noted it is related to pre-existing structure/chemistry--related to local NMC, but where does the heterogeneity come from? Heterogeneity comes during discharge, and it is Li-metal heterogeneity that causes heterogeneity in cathode. The reviewer noted that operando measurements of Li-metal a big advance

Reviewer 6

The reviewer noted that one of the conclusions from Li-plating and stripping experiment from synchrotron XRD suggest strong inhomoegeneity observed during discharge. One comment stated, "Conventional wisdom says Li-deposition is the challenge," and the reviewer likes to know how broad is the statement. Li-plating process can be highly non-uniform as well. The reviewer cited good progress that has been towards applying X-ray spectroscopy for studying the TM dissolution with and without $LiPO_2F_2$ additive, and the X-ray tomography aided by AL-ML approaches used to quantify degree of cracking in 811 cathodes.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer commented the team has been extensively collaborating with other teams in the Battery500 Consortium, providing the critical information for other teams to further optimize the materials they are developing. The synergistic effect among the teams is reflected by the fruitful publications and presentations.

Reviewer 2

The reviewer remarked the team works in close collaboration with other Battery500 partners. SPAN samples provided by UCSD, electrolyte additive and SEI (Army Research Lab). High-Ni NMC provided by UT-Austin.

Reviewer 3

The reviewer said the team is in close collaboration with almost all Battery500 teams.

Reviewer 4

The reviewer said the team has collaborators from universities and other national labs. All contributions from the collaborating teams are clearly listed. The team may consider develop collaborations with industrial partners.

Reviewer 5

The reviewer said many collaborators with both universities and labs, and no industry collaborators

Reviewer 6

The reviewer said the collaboration within the project team is good, but no industry contributions are specified. This project seems to collaborate with national labs and other external entities. But it is yet to be done. The reviewer said it might be good to show the performance in LiFSi so that it can be combined with Nb coated NMC811 (Stan) and LATP coated separator (Yang).

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer remarked unique capability to answer questions that have long been outstanding.

Reviewer 2

The reviewer said the team is on the right track in conducting the project and the proposed future work is continuing on what the team is doing well now but aiming at new problems.

Reviewer 3

The reviewer said the proposed future research can achieve its target to some extent. It might be good to focus on one MNC811 or S. It is important to discuss the changes on Li electrodes during charge/discharge.

Reviewer 4

The proposed future research directions are rational and cover the most critical problems which need to be tackled for future progress.

Reviewer 5

The reviewer commented the proposed future work is well based on previous studies and is a good step forward in achieving optimized battery performance in various battery systems. The characterization technique is feasible in understanding the proposed scientific problems. It will be nice to see more integration of the characterization with modeling effort in future work.

Reviewer 6

The reviewer said more specific goals and details needs to be provided as part of future research needs. The high level science goals are excellent but how do they connect to specific objectives and milestone for Battery500?

*Question 5: **Relevance: Does the project support the overall VTO subprogram objectives?***

Reviewer 1

The reviewer remarked the team is working on increasing the energy density of Li-metal batteries using advanced techniques, which is directly supporting the VTO's objective in vehicle electrification.

Reviewer 2

The reviewer said the techniques are aimed precisely at solving the problems of Battery500.

Reviewer 3

The reviewer said yes, it supports overall VTO program objectives.

Reviewer 4

The reviewer commented this project is focused on using advanced tools and characterization for studying bulk and interfaces involving Li-metal and high voltage cathode. This work supports development of high energy density Li-ion.

Reviewer 5

The reviewer remarked the team developed and deployed characterizations, especially synchrotron methods, to assist the optimization of cathode materials and improvement of cell designs. It is supportive of DOE's battery objectives in achieving high energy density and long cycle life batteries.

Reviewer 6

The reviewer pointed out that understanding the failure mechanism is the prerequisite for extended battery life with improved energy density.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said resources are sufficient.

Reviewer 2

The reviewer said the project (second phase) is just starting. The funding level ($75 million for 5 years) is proper.

Reviewer 3

The reviewer said the team has what it needs.

Reviewer 4

The reviewer said proposed project milestones are achieved in a timely fashion.

Reviewer 5

The reviewer said ongoing collaboration listed in the presentation is a good proof that the resources of the project are sufficient, not only from the expertise from the teams, but also from the spectrum of work scope.

Reviewer 6

The reviewer commented the work requires constant access to the user facilities and close collaboration with partner teams. The current resources seem to be sufficient to conduct the proposed work.

Presentation Number: bat368
Presentation Title: Full Cell Diagnostics and Validation to Achieving High Cycle Life
Principal Investigator: Eric Dufek, Idaho National Laboratory

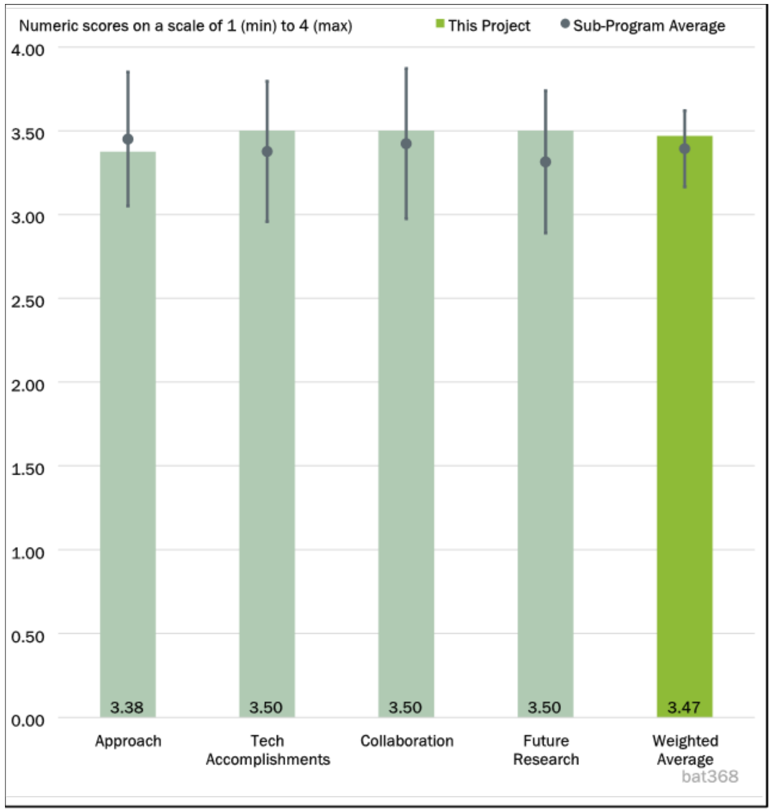

Figure 2-9 - Presentation Number: bat368 Presentation Title: Full Cell Diagnostics and Validation to Achieving High Cycle Life Principal Investigator: Eric Dufek, Idaho National Laboratory

Presenter

Eric Dufek, INL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer remarked the team has conducted experiments and modeling for the performance of Li-ion batteries as well as Li-S batteries, and published five journal papers one in Nature Energy and one in Advanced Energy Materials.

Reviewer 2

The reviewer noted the team's approach is to understand impact of electrolyte on SEI and use the understanding to improve cycle life of Li-ion and Li-S cells.

Reviewer 3

The reviewer said the team conducted research at a pouch level by adjusting pressure and processing temperature. This is an essential complement to the battery research in materials level.

Reviewer 4

The reviewer noted good approaches, but did not see anything novel.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The two milestones completed in fiscal year (FY) 2022 are well presented and reflect actual progress in developing the Li-S battery. The applied pressure changes the porosity and tortuosity of the cathode and has clear effects on the cycling stability. Real-time pressure monitoring can be used as a tool to predict cell failure.

The reviewer asked the team how could the pressure be applied to the cell in the battery application, either to realize better performance or monitor the condition, without significantly increasing the cost? The reviewer also noted the team investigated the temperature effects in the formation cycle on the cycling performance of Li/NMC pouch cells. The results show that the room temperature (25°C) is the best condition.

Reviewer 2

The reviewer said the team developed good understanding on the impact of external pressure for Li/S cells and the impact of LHCE on SEI of Li metal rechargeable cells.

Reviewer 3

The reviewer noted that two milestones have been completed successfully, with another two are on track. The team studied the pressure effect on batteries, and investigated porosity and totuosity effects. The team explored the effect of localized high concentration electrolyte, along with the solvation driven morphology. The team published high quality of journal papers.

Reviewer 4

The reviewer said very modest pressures give higher Li density, as expected. Pressure reduces cracking in cathode, surprising. The reviewer noted that looking at separator constriction is new and important. Results are mainly empirical with little effort at fundamental understanding, perhaps appropriate for a development project.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The team collaborates with all battery 500 PIs, students, and postdocs. It is better to indicate the contributions or roles of the collaborators to the specific project (Bat 368).

Reviewer 2

The reviewer noted that the research team works with universities and national labs. The technical approaches have been shared with other team members within the consortium for their batteries assessment.

Reviewer 3

The reviewer said Battery500 has very good collaboration throughout.

Reviewer 4

The reviewer noted that INL is part of the Battery500 team.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said the team is going to refine the established methods, and also expand them to pouch cells, for Li/NMC and also Li-S.

Reviewer 2

The reviewer remarked focus on calendar life is highly important.

Reviewer 3

The reviewer remarked it is better to be more specific about future research plans, and asked will the team continue the pressure studies or some other methods are to be developed and adopted for evaluating the impact on battery cells of different applying conditions?

Reviewer 4

The reviewer said the team needs to provide insights on fixed pressure versus fixed gap on cycle life of Li metal cells.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer remarked research at a cell level is important in boosting the performance of the Li-S and Li-metal batteries.

Reviewer 2

The reviewer remarked the research is critical for advancing to practical cells.

Reviewer 3

The reviewer remarked the research is relevant to materials and batteries analysis. The results will also be relevant for electrification as they are valuable for batteries study.

Reviewer 4

The reviewer said the work met the Battery500 program objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said resources are adequate.

Reviewer 2

The reviewer said funding is sufficient.

Reviewer 3

The reviewer was not clear how many resources are utilized for the specific project (bat368). The overall funding level to the Battery500 is adequate.

Reviewer 4

The reviewer pointed out there are $15 million to distribute for the next stage. The refinement and expansion of the methods to other materials/batteries (pouch cell) will not cost too much for consumables. The reviewer noted manpower cost should be similar to that of last year.

Presentation Number: bat369
Presentation Title: High Energy Rechargeable Lithium-Metal Cells, Design, Fabrication and Testing
Principal Investigator: Jie Xiao, Pacific Northwest National Laboratory

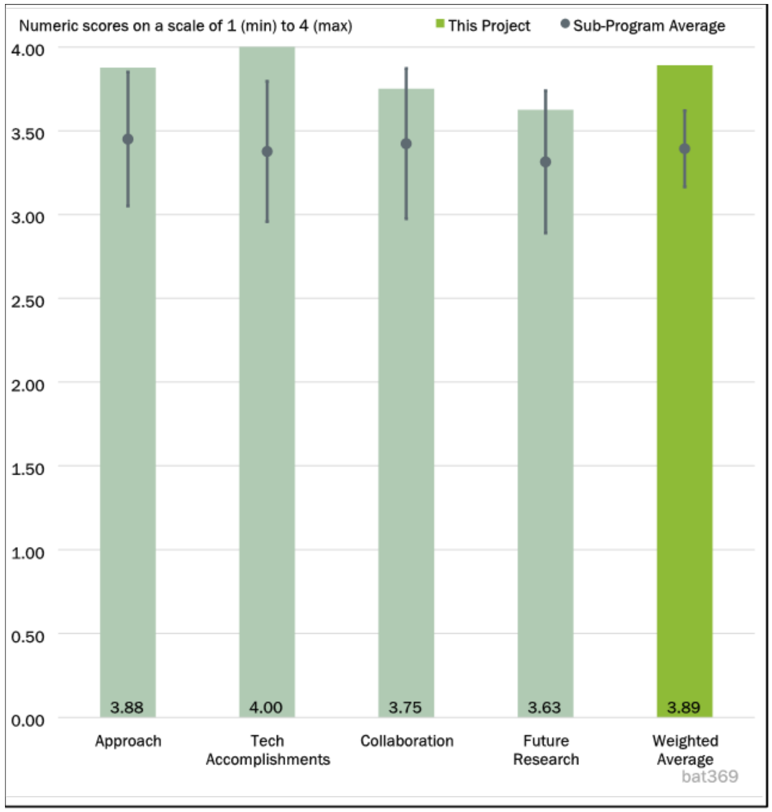

Figure 2-10 - Presentation Number: bat369 Presentation Title: High Energy Rechargeable Lithium-Metal Cells, Design, Fabrication and Testing Principal Investigator: Jie Xiao, Pacific Northwest National Laboratory

Presenter

Jie Xiao, PNNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer noted that PNNL as the leading team of the Battery500 consortium, gives a report on the overall approach and achievements of the project. The aim of the project is to develop high-energy Li-metal pouch cells up to 500 Wh/kg. The reviewer thought one of the important advantages of the approach is combining and focusing the strengths of nation-wide universities, national laboratories, and industrial partners to solve a very critical problem in batteries.

Reviewer 2

The reviewer noted that the team fabricated pouch cells with 350 Wh/kg capacity (2 Ah) using Li/NMC622 and achieved 600 stable cycles. The mechanism for the long stability and also the failure of the battery has been explored. The team published one paper in Nature Energy. Thin Li anode (20 micron) is found to be more effective than the thick one (greater than 50 microns). The reviewer said even higher capacity pouch cell at 400 Wh/kg (2.5 Ah) has been made and found to cycle greater than 200 times (on going).

Reviewer 3

The reviewer remarked developing design principles is extremely valuable. So is understanding dynamic interactions among cell components.

Reviewer 4

The reviewer commented the project approach is well designed and focused on achieving both cycling and high specific energy. The journal publications by the team that lay out their approach regarding high-energy pouch cells are important and impactful, and clearly move the project beyond the typical coin cell/single layer cell work of academic groups. The reviewer noted there is a strong quantitative road map already in place, which is very important for the approach.

The only concern this reviewer had with the approach is using a low charging rate of C/10. While this could work for some delivery vehicles, it is not expected to work for passenger vehicles, and the cycling stability optimization approach for a 1C or 2C charge rate is almost certainly different than a C/10 rate. The reviewer encouraged this effort to collect some data on 1C charge rate, to provide the community a sense for how the cells would do at that rate.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer noted the research team has achieved more than the objectives originally planned. The other objectives are on track with excellent results demonstrated.

Reviewer 2

The reviewer said the consortium has made exciting progress in the well-planned project. The team has realized 350 Wh/kg pouch cell at 600 stable cycles in 2021 and is working on a 400 Wh/kg cell, which already reached 200 cycles.

The team presents an interesting study on the effect of Li-metal thickness on the cycling performance of Li-metal batteries. The reviewer said the dry/wet SEI explanation is plausible but not well supported by experiment and/or theory. One of the shortcomings of a thin (20 um) Li film is that it reduces the length of vertical channels in the Li anode and therefore increases the local current density.

Reviewer 3

The reviewer said results from the cell building efforts appear outstanding. Getting high-energy, multi-layer, Ah class pouch cells with Li-metal to cycle well is very difficult, and the results speak for themselves. There is a clear roadmap and testing pipeline, and the milestones are being reached. The reviewer said the team is clearly quantifying the influence of key variables (e.g., electrolyte and Li amounts) on cycling performance.

The reviewer offered as one small suggestion, the “dry” versus “wet” SEI hypothesis would benefit from greater empirical evidence. While the sketches are plausible, as the team likely knows there are other possible explanations, and additional work could be done to strengthen the explanation presented.

Reviewer 4

The reviewer said Phase 1 was amazingly successful, but way too much time was spent talking about Phase 1. As a result, the talk was much too long, substantially reducing chances for questions by judges. Explanation for why thicker Li gives poorer results is very insightful. The reviewer is eagerly awaiting experimental confirmation.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said the strength of the Battery500 consortium is in the collaboration crossover of the nationwide institutes with expertise in all different aspects of battery research and development.

Reviewer 2

The reviewer noted that Battery500 is a large team, with many institutions, and individuals with a range of priorities, which is very difficult to manage. However, it appears the team is functioning well together, and the connections among the efforts, including the cell building activity, are clear and appropriate. The reviewer noted that the cell building team has an important leadership role in the project because it is the ultimate metric to assess progress, and the leadership in this activity appears strong.

Reviewer 3

The reviewer noted the team works closely with industrial partners (eight), universities (nine) and national labs (three) in fabricating the pouch cell using NMC/Li for high energy density batteries.

Reviewer 4

The reviewer remarked Battery500 has very good collaboration throughout.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer remarked future research is well defined with the objective of realizing 500 Wh/Kg Li-metal cell. Because the second phase of the project just started, this reviewer is optimistic about the final success of the project. The tasks and contributions of each collaborating institutes are clearly indicated.

Reviewer 2

The reviewer said the team has done an excellent job articulating a roadmap for future work to get to 500 Wh/kg, and the proposed work fits into that roadmap well. The future targets are challenging, but at least for the coming year it seems likely they will be achieved.

Reviewer 3

The reviewer said the team is moving towards 500 Wh/kg cell in its future plan. This is ambitious and also achievable based on its current accomplished technical achievements.

Reviewer 4

The reviewer said improved utilization of metal is a very important insight that will impact how people think.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said yes, the project supports the overall VTO objective very well.

Reviewer 2

The reviewer said the project is relevant to batteries, materials synthesis, and analysis, also eventually impact on electrification (EVs).

Reviewer 3

The reviewer said this is aimed at the heart of Battery500.

Reviewer 4

The reviewer remarked the project is clearly relevant. As mentioned above, this reviewer's main concern is the use of a C/10 charge rate, and how this large effort and optimization is done for this charge rate, while at least for passenger applications a rate of 1C or 2C (or higher!) is more relevant. Just collecting and presenting some data at higher charge rates would be very helpful for the community.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer noted that this is a large program, and that is appropriate, given the range of activities and the need to produce pouch cell results.

Reviewer 2

The reviewer said the funding level ($75 million for 5 years starting 10/1/2021) is adequate for the project.

Reviewer 3

The reviewer said resources are sufficient.

Reviewer 4

The reviewer noted there are $15 million for the consortium for the next stage. The reviewer believed industrial partners can also make some contributions.

Presentation Number: bat496
Presentation Title: Silicon Consortium Project: Advanced Characterization of Silicon Electrodes
Principal Investigator: Robert Kostecki, Lawrence Berkeley National Laboratory

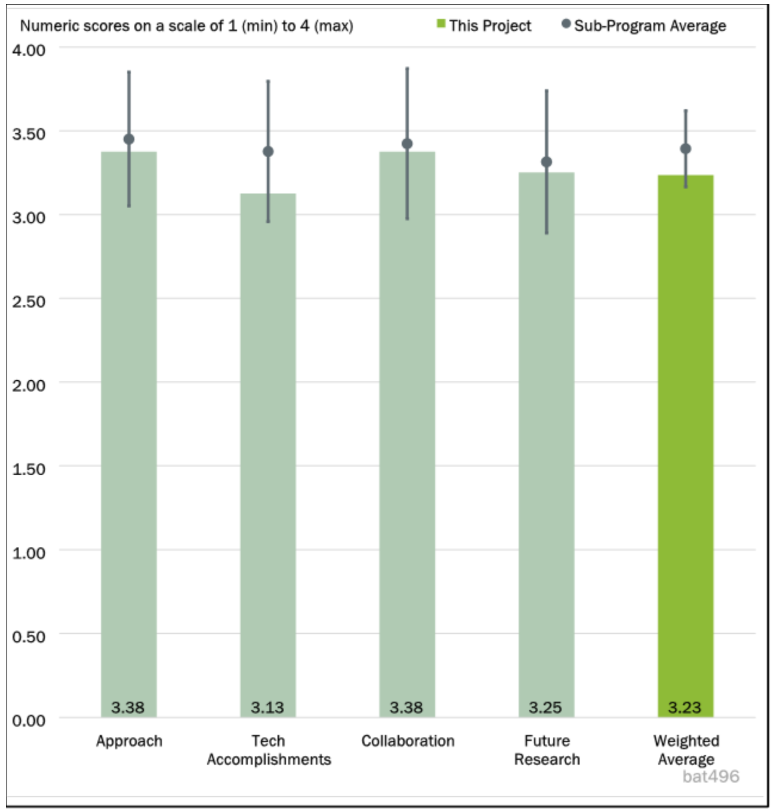

Figure 2-11 - Presentation Number: bat496 Presentation Title: Silicon Consortium Project: Advanced Characterization of Silicon Electrodes Principal Investigator: Robert Kostecki, Lawrence Berkeley National Laboratory

Presenter

Robert Kostecki, LBNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said that yes, the project is well designed and the timeline is reasonably planned.

Reviewer 2

The reviewer mentioned that the approach taken by the team to study Si surface is very essential to the use of Si in Li ion batteries. The reviewer added that the approach is put together well to cover a wide range of options focusing on this problem from different directions.

Reviewer 3

The reviewer said that the project has a set of well-defined objectives and the tasks have been structured around those objectives.

Reviewer 4

The reviewer stated that the approach is quite comprehensive, utilizing a wide range of characterization techniques such as nano-Fourier-transform infrared spectroscopy (FTIR), neutron reflectometry, cryo-TEM/ electron energy loss spectroscopy, NMR, scanning spreading resistance microscopy, SEM- energy-dispersive X-ray spectroscopy, and Raman. The reviewer added that however, it is unclear whether the measurements were performed on the same Si baseline material. The reviewer added that it is also unclear whether some of these techniques, such as nano-FTIR and neutron reflectivity, could be applied to Si-composite electrodes which are non-planar. The reviewer declared that the influence of the polymeric binders on the composition and structure of the SEI and calendar life of the Si-composite electrodes should be investigated.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer said that yes, it is as planned.

Reviewer 2

The reviewer suggested that it would be helpful to clearly delineate technical accomplishments made during this budget period as several results presented were published prior to the current budget period.

Reviewer 3

The reviewer claimed that there has been a great deal of effort placed to the development of analytical techniques, and that there has been terrific progress in this area. The reviewer noted that in parallel the techniques have generated a range of hypotheses for potentially observable phenomena, but little effort has been placed to date to pursue those observations. The reviewer concluded that this should be part of the future work and the reviewer looks forward to seeing this. The reviewer said that it will not only enhance this particular project's accomplishments but support several of the other Silicon Consortia projects.

Reviewer 4

The reviewer stated that the activities done by the teams capture a variety of characterization techniques, but that the results are not progressing towards a common answer. The reviewer added that the solution from the activity is creating more problems that seem too complex to solve than progress towards a robust reliable solution.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer claimed that there is outstanding collaboration between the various teams in the program.

Reviewer 2

The reviewer stated that the collaboration is excellent, but that it would be better to have some collaboration with industrial companies.

Reviewer 3

The reviewer noted that the collaboration is largely within the National Labs. The reviewer suggested that it may be helpful to extend the collaboration to companies that can make the best performing Si-electrodes in terms of calendar and cycle life. The reviewer added that it may also be helpful to extend the collaboration to universities that have some unique capabilities, such as mechanical characterization, and that it would be helpful to group the large number of collaborators to teams and highlight their individual contributions. The reviewer observed that it may be an oversight that one of the collaborators (Muhammad Ihsan Ul Haq) was listed twice on the “Collaboration and Coordination with other Institutions” page.

Reviewer 4

The reviewer said that it is clear that the methods developed here are being shared with the other Consortia members and that there is progress, as a result of this work. It appears to the reviewer that most of the other labs and teams of recipients of this project’s work and don’t necessarily directly contribute to the developments in this project. The reviewer suggested that the Principal Investigator should incorporate references to joint work on the individual slides.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer claimed that the project clearly defined a purpose for future work, and that it would be very interesting to learn more about the efficacy of the artificial SEI, i.e., Langumir-Blodgett surface film.

Reviewer 2

The reviewer stated that one of the items under Future Plan, “Explore and study range of silicon and silicon-carbon model systems materials...,” should include studying the best performing Si-containing electrodes made by companies, especially those with DOE VTO funding.

Reviewer 3

The reviewer commented that proposed future work opens up several new paths towards an answer but that the program needs to focus on a solution that is reasonable for today’s application while balancing the compromises needed to achieve the solution.

Reviewer 4

The reviewer explained that the score was a little lower than it could be, mainly because of the breadth of work that can come out of this project. The reviewer suggest that the PI may have to end up prioritizing the areas of focus. The reviewer added that the future work is otherwise highly relevant, when evaluated against the project’s and consortium’s goals.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer commented that Silicon is a promising anode candidate for high energy batteries, such as for EV.

Reviewer 2

The reviewer stated that it is highly relevant to the Battery subprogram.

Reviewer 3

The reviewer claimed that the project is very much relevant as Si-based anode will open the battery industry to achieve higher energy utilization as a complete product.

Reviewer 4

The reviewer noted that the analytical methods developed here do not need to apply strictly to silicon anodes, and for this reason this project is highly relevant.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated that the resources are amazing for characterizations.

Reviewer 2

The reviewer claimed that the team has excellent resources for advanced characterization of silicon electrodes.

Reviewer 3

The reviewer declared that resources allocated to the project are sufficient to achieve its stated goals.

Reviewer 4

The reviewer observed that the resources on this project are assumed to be those responsible in the development and validation of the test techniques, and then otherwise shared with joint projects. The reviewer concluded that, to that end, the project appears to be nicely balanced.

Presentation Number: bat497
Presentation Title: Silicon Consortium Project: Electrochemistry of Silicon Electrodes
Principal Investigator: Christopher Johnson, Argonne National Laboratory

Presenter

Christopher Johnson, ANL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

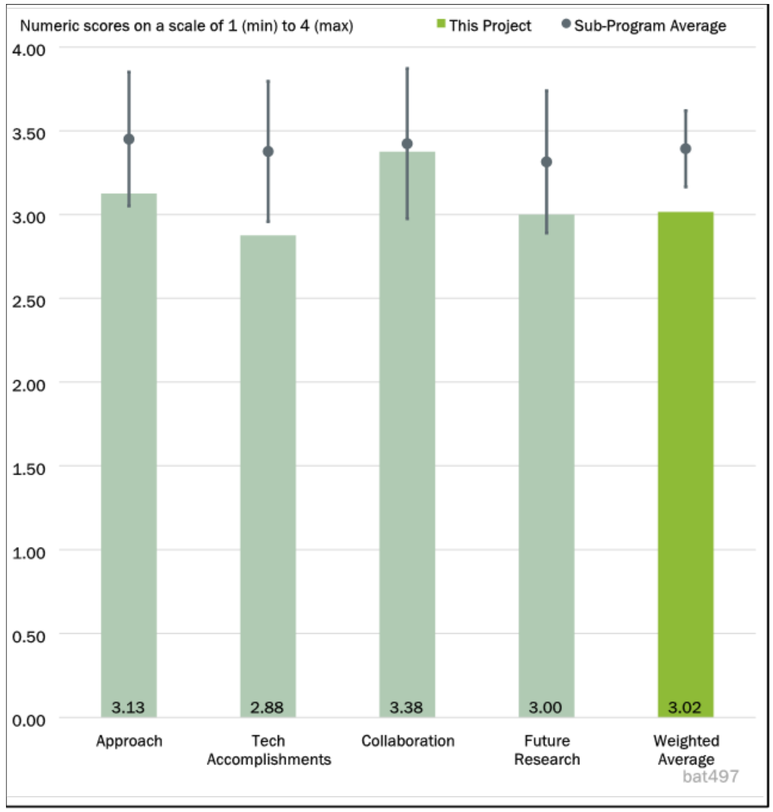

Figure 2-12 - Presentation Number: bat497 Presentation Title: Silicon Consortium Project: Electrochemistry of Silicon Electrodes Principal Investigator: Christopher Johnson, Argonne National Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer commented that yes, the project is well designed, and the timeline is reasonably planned.

Reviewer 2

The reviewer expressed that the Voltage Hold method does not seem to be a robust quantitative method for evaluating the calendar life of full cells containing silicon in the negative electrode. The reviewer added that even under ideal conditions, it only provides qualitative information related to the calendar life. The reviewer suggested that the team should quickly decide whether this method should be dropped from the project and focus on developing a more quantitative calendar life evaluation method.

Reviewer 3

The reviewer remarked that the stated goal of identifying a technique to screen materials using a short-term test for the calendar life problem is very interesting to explore, but that the data shows that this process is more complex and the test is not going to be really short term. The reviewer noted that more understanding into the mechanism of failure in the voltage hold test will give better pathway towards defining a more realistic pass/fail criteria.

Reviewer 4

The reviewer declared that the majority of the effort has been based around voltage hold (Vhold) method development, validation of the method and validation of materials selection via the method. The reviewer added that the project is now moving to the other methods selected for electrochemical analysis. The reviewer observed that the timing appears relatively open-ended, and the reviewer is not convinced the timeline is being considered as relevant to the project.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer expressed that it is as planned.

Reviewer 2

The reviewer stated that the Vhold approach has been well developed as a qualitative method, and that it can be extended to other work groups. The reviewer added that there were some other studies shown and these appear as incomplete at this point in time. The reviewer expressed that the scanning electrochemical microscopy method is an example of this and that it will be nice to see this development get fleshed out in the coming year. The reviewer articulated that the aged cells analysis was not presented in a manner as complete as expected so that the conclusions shown were acceptable, but that further discussion after the presentation with some of the investigators resolved the reviewer's concerns.

Reviewer 3

It seemed to the reviewer that the team spent much of its effort in demonstrating the ineffectiveness of the Voltage Hold method for evaluating the calendar life, though it could have been predicted since the calendar life should be evaluated under the open circuit condition, i.e., without an externally applied driving force, e.g., the applied potential.

Reviewer 4

The reviewer claimed that the validation process for developing this technique will take time, and that accelerating these processes causes new reactions that are creating a lot of noise in the study. The reviewer recommended that the focus of the work needs to be narrowed to study how the acceleration is affecting the anode and how it can be related to the mechanism in long term tests.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer observed that there is outstanding collaboration between the various teams in the program.

Reviewer 2

The reviewer noted excellent collaboration and suggested that it may be better to have some industrial collaboration.

Reviewer 3

The reviewer declared that the collaboration is mainly among several National Labs.

Reviewer 4

The reviewer would like to see a little more engagement on evaluating different Si materials and electrode structures coming from the other labs. The reviewer clarified that this would really reinforce the electrochemical methods validation. The reviewer suspected that this will be the case as the scanning electrical mobility spectrometer method becomes employed by the other projects.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer noted that calendar life is critical and gassing on anode side is an enemy. The reviewer suggested that more work needs to be done on gassing mechanism analysis which may be very helpful to find effective additives for Si-based anode if there are any.

Reviewer 2

The reviewer declared that the team did not disclose much detail other than stating, under Proposed Future Research, "Develop electrochemical impedance methods on pouch cells to electrochemical impedance methods on pouch cells to measure Si equilibrium kinetics and its affect on calendar life." It was unclear to the reviewer how high frequency electrochemical impedance spectroscopy (EIS) could be helpful to evaluate the very slow (hundreds of hours) Si equilibrium kinetics.

Reviewer 3

The reviewer expressed that future work needs to focus on the relationship between the short-term test and long-term test.

Reviewer 4

The reviewer claimed that the PI indicated that more involvement with electrochemical modeling is needed, and this should be included the future work. The reviewer otherwise agreed with the proposed future work.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer stated that silicon is a promising anode candidate for high energy batteries, such as for EV.

Reviewer 2

The reviewer noted that the project supports the overall VTO objectives on EV batteries.

Reviewer 3

The reviewer claimed that the project is very much relevant as Si-based anode will open the battery industry to achieve higher energy utilization as a complete product. The reviewer added that developing a short-term test will reduce product development time and save cost for the battery industry.

Reviewer 4

The reviewer declared that the methods employed are very useful in directing materials selection and electrode characterization. The reviewer said that they can be used across the consortium and on other programs.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer mentioned that the team has excellent experimental and modeling capabilities.

Reviewer 2

The reviewer claimed that the resources are sufficient.

Reviewer 3

The reviewer observed that the resources allocated to the project are sufficient to achieve its stated goals.

Reviewer 4

The reviewer saw no issues with respect to the resources employed in this work.

Presentation Number: bat498
Presentation Title: Silicon Consortium Project: Next-Generation Materials for Silicon Anodes
Principal Investigator: Nathan Neale, National Renewable Energy Laboratory

Presenter

Nathan Neale, NREL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

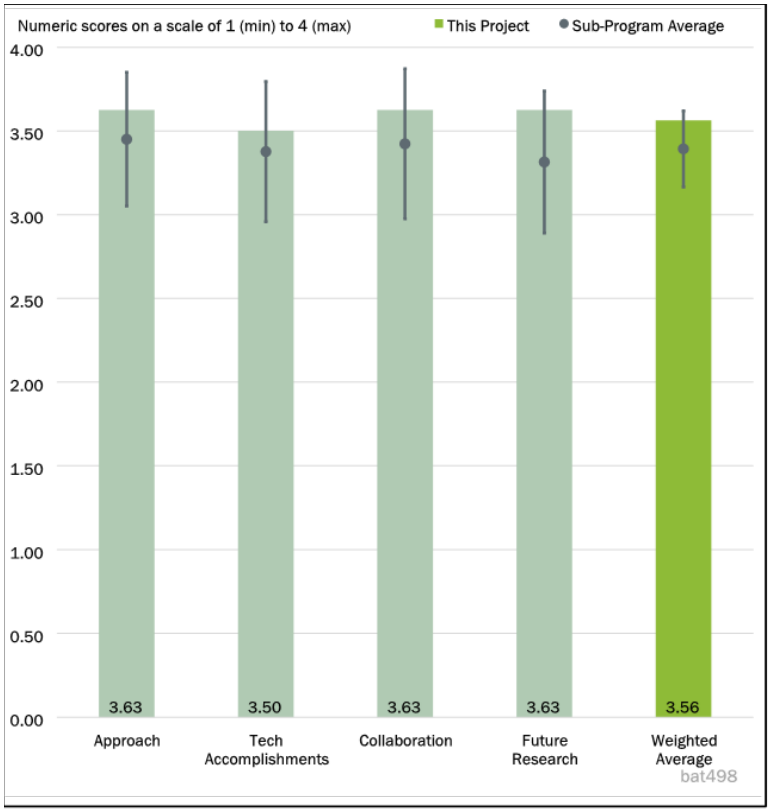

Figure 2-13 - Presentation Number: bat498 Presentation Title: Silicon Consortium Project: Next-Generation Materials for Silicon Anodes Principal Investigator: Nathan Neale, National Renewable Energy Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer noted that the project is well designed and the timeline is reasonable.

Reviewer 2

The reviewer commented that the approach to study different methods of Si manufacturing and how these techniques affect material property and thereby cycling/calendar aging is remarkable. The reviewer declared that the team's focus on working on techniques that have high yield and relatively low cost makes this project more relevant.

Reviewer 3

The reviewer observed that the work was diverse, covering a wide set of candidate materials. The reviewer added that the project has addressed several of the barriers and is now prioritizing the work.

Reviewer 4

The reviewer claimed that although Splat Quenching and Laser Quenching are among the known rapid quenching methods of forming amorphous alloys from the respective molten alloys, solid state reactions (e.g., annealing at a temperature which allows inter-diffusion but not crystallization) and mechanical alloying (e.g., ball milling) have emerged since the 1980s as alternative ways of making some amorphous alloys, including silicon-nickel (Si-Ni) and other Si-containing amorphous alloys. The reviewer suggested that the team may look up publications since the 1980s to evaluate whether these methods of forming amorphous alloys are more cost effective and scalable than the splat and laser quenching methods for making Si-containing amorphous alloys for Li-ion battery applications.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer expressed that the success in understanding how each technique affects material surface is evident in the results presented. The reviewer concluded that it is encouraging to see that more than two techniques have yielded promising results.

Reviewer 2

The reviewer said it is as planned.

Reviewer 3

It was unclear to the reviewer why PEO works well for Si nanoparticles made by Plasma-enhanced chemical vapor deposition (PECVD), but PEO does not work for Si nanoparticles made by the milling process. The reviewer explained that milling single crystal ingots to form Si nanoparticles seems to be an expensive endeavor since it is already expensive to form these single crystal boules. The reviewer recommended that the team should perhaps mill metallurgical grade Si polycrystals to form low-cost Si nano-particles for Li-ion battery applications.

Reviewer 4

The reviewer stated that the initial approach was to find methods to produce meaningful amounts of suitable Si. The reviewer claimed that this has been achieved and the project has moved to electrode engineering. The reviewer added that it is known that the industry has made considerable progress in the development of high Si content anode materials and electrodes, and feedback from their lessons learned into progress here would be very valuable, if it is possible.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer observed that there is outstanding collaboration between the various teams in the program.

Reviewer 2

The reviewer noted great collaborations and recommended that it would be better to have some collaboration with industry.

Reviewer 3

The reviewer suggested that the team may consider expanding collaborations to include experts on making Si-containing amorphous alloys by solid-state reaction or ball milling.

Reviewer 4

The reviewer remarked that the PI clearly recognizes the need for collaboration within the consortium and makes good use of it. The reviewer noted that it would be good if additional collaboration from industry would be possible, but this might dilute the efforts in meeting project scope. The reviewer clarified that it would be specifically great if a comparison on electrode fabrication could be made between the lab material and some commercially available high-Si content materials.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer remarked that studying electrolyte interaction is critical as each of these techniques creates new and different interactions. The reviewer added that developing 3D electrodes and strategically designed surfaces creates more excitement towards the future work. The reviewer concluded that the approach is very well thought off and executed by the team.

Reviewer 2

The reviewer noted the well prioritized tasks and good use of the work products from the other Consortium projects.

Reviewer 3

It seemed to the reviewer that the utilization of the Si is low (1000m Ah/g capacity vs.76%–80% Si in anode), which needs to be addressed.

Reviewer 4

The reviewer recommended that the team should figure out why PEO works well for Si nanoparticles made by PECVD, but does not work well for Si nanoparticles made by the milling process.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer claimed that Si is a promising anode candidate for high energy batteries, such as for EV.

Reviewer 2

The reviewer declared that the project is highly relevant to the Battery subprogram objectives.

Reviewer 3

The reviewer expressed that the project is very much relevant as Si-based anode will open the battery industry to achieve higher energy utilization as a complete product.

Reviewer 4

The reviewer stated that this project is central to achieving the Consortium goals, and can expand and contract effectively with Consortium scope prioritization and scope adjustments as it is sufficiently agile.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated that the resources are sufficient.

Reviewer 2

The reviewer noted that the resources allocated to the project are sufficient to achieve its stated goals.

Reviewer 3

The reviewer agreed with the PI's statement indicating that the project is most successful with the appropriate level of collaborative support.

Reviewer 4

The reviewer said that although the team has sufficient resources, it may consider collaborations with experts on amorphous alloys and mechanical characterizations.

Presentation Number: bat499
Presentation Title: Silicon Consortium Project: Mechanical Properties of Silicon Anodes
Principal Investigator: Katherine Harrison, Sandia National Laboratories

Presenter

Katherine Harrison, SNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

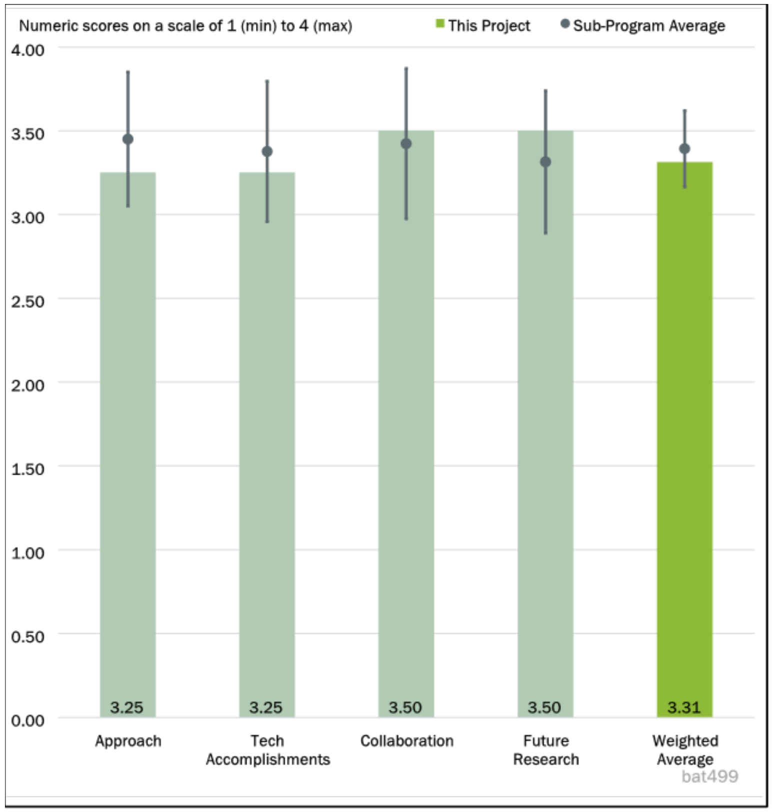

Figure 2-14 - Presentation Number: bat499 Presentation Title: Silicon Consortium Project: Mechanical Properties of Silicon Anodes Principal Investigator: Katherine Harrison, Sandia National Laboratories

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer stated that the project is well designed and the timeline is reasonable.

Reviewer 2

The reviewer claimed that the approach to study the mechanical property of Si anodes is critical towards commercialization.

Reviewer 3

The reviewer expressed that the approach taken by the mechanical characterization thrust is comprehensive. The reviewer observed that some of the characterization methods, however, seem to be more useful than others. The reviewer clarified that for example, microcalorimetry results were inconsistent with the electrochemical test results, probably because microcalorimetry was not done under realistic cell operating conditions.

Reviewer 4

The reviewer commented that the structure of the work is appropriate for the project objectives. The reviewer added that the work is also well prioritized. What was not as clear to the reviewer was how this work overlaps with the electrode structure development work in the adjacent projects. The reviewer clarified that this is important to note since this project does not just address mechanical characterization of the electrode but also steers electrode design.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer observed that the team is focusing on the techniques that work and has promising results which has streamlined the project and helped narrow the task. The reviewer stated that the mechanical perturbation is an interesting approach.

Reviewer 2

The reviewer said it is as planned.

Reviewer 3

The reviewer declared that the results highlight the importance of mechanical degradation. The reviewer added that the more detailed characterization of the mechanical properties, at various stages of calendar aging and cycle number, would be necessary to understand degradation mechanisms.

Reviewer 4

The reviewer remarked that progress has been good, but that it is also clear that additional electrode structural optimization is needed. The reviewer noted that this includes the areas of other binder candidates, which will play an increasing role in the higher loading electrodes.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer noted that there is outstanding collaboration between the various teams in the program.

Reviewer 2

The reviewer noted the excellent collaborations and said that it would be better if the team included industrial collaboration as well.

Reviewer 3

The reviewer mentioned that collaborations are mainly among the National Labs, and that it may be helpful to expand collaborations to include experts on characterization of mechanical behavior of Si-electrodes to help solve mechanical damages especially in high loading Si cells.

Reviewer 4

The reviewer stated that the team collaborates well with other project teams. The reviewer added that it might be helpful to consult with industrial materials suppliers for additional experience in materials selection and evaluations. The reviewer concluded that this is potentially most beneficial in the binder system, but could also extend to the selection of current collector materials (e.g.: copper/nickel composites) and conductive additives.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer stated that future work is clearly defined, and that large format cells (i.e., 3-5Ah) are recommended for study on gas generation and stability. The reviewer clarified that in coin cells, it is not possible to observe gas generation.

Reviewer 2

The reviewer said that hopefully, more insights can be gained to help understand the degradation mechanisms caused by the many parameters identified by the team, such as, Si material, electrode manufacturing conditions, electrochemical aging/cycling protocols, pouch versus coin cells, and size and loading of the electrodes.

Reviewer 3

The reviewer noted that the team's focus on understanding the influence of mechanical effect in the life of Si anode is very well reflected in the future work.

Reviewer 4

The reviewer observed a very good choice of future thrust areas, and added that this could be helped by collaboration on optimizing the non-active materials components.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer remarked that the success in this project is essential in moving the consortium ahead. The reviewer added that it will also provide the platform to evaluate alternative Si-containing active materials. The reviewer exclaimed that the team did good work.

Reviewer 2

The reviewer claimed that Si is a very promising anode candidate for high energy batteries, such as for EVs.

Reviewer 3

The reviewer affirmed that the project supports the VTO battery objectives.

Reviewer 4

The reviewer declared that the project is very much relevant as Si based anode will open the battery industry to achieve higher energy utilization as a complete product.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer claimed that the resources are sufficient.

Reviewer 2

The reviewer noted that the resources allocated to the project are sufficient to achieve its stated goals.

Reviewer 3

The reviewer observed no issues and good collaboration with adjacent teams.

Reviewer 4

The reviewer suggested that it may be helpful to expand external collaborations to strengthen mechanical characterization. The reviewer added that this may help determine which of the many hypothetical parameters are important in affecting the calendar and cycle life of Si-containing electrodes.

Presentation Number: bat500
Presentation Title: Silicon Consortium Project: Science of Manufacturing for Silicon Anodes
Principal Investigator: Gabriel Veith, Oak Ridge National Laboratory

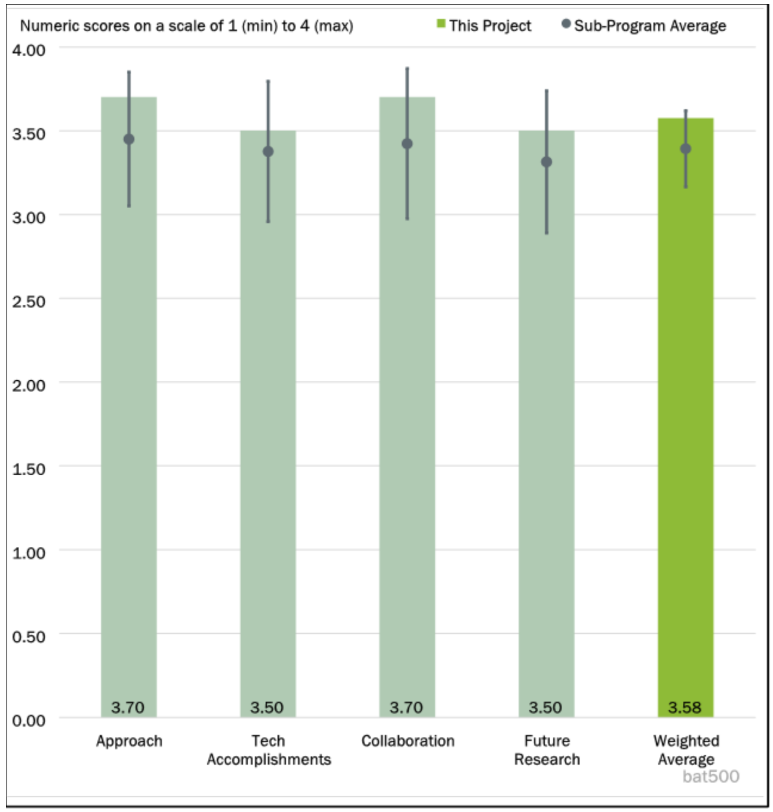

Figure 2-15 - Presentation Number: bat500 Presentation Title: Silicon Consortium Project: Science of Manufacturing for Silicon Anodes Principal Investigator: Gabriel Veith, Oak Ridge National Laboratory

Presenter

Gabriel Veith, ORNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer noted that the focus on reproducibility and process control is especially critical to the development of high-capacity thick Si electrodes for automotive applications.

Reviewer 2

The reviewer remarked that the project is well-designed and the timeline is reasonable.

Reviewer 3

The reviewer declared that the team's approach to understanding electrode manufacturing issues is excellent. The reviewer added that the methods used to eliminate noise in development and testing are very well thought off and executed.

Reviewer 4

The reviewer commented that the work has addressed several important issues related to Si-based anode materials such as low initial coulombic efficiency, low loading electrode, poor cycle life, etc. The reviewer added that the approaches taken seemed reasonable and effective.

Reviewer 5

The reviewer observed that although the 200-600g per batch rate may be sufficient for producing enough Si electrode materials for the project team members, it is unclear whether manufacturing science fundamentals and knowledge gained at this batch level could be scaled to the eventual industrial-scale production of Si-containing electrodes for EV applications. The reviewer suggested that the team may develop and test scaling relationships for manufacturing Si electrodes over a wide range of batch sizes. The reviewer added that since evaporation is a line-of-sight deposition process, pre-lithiation of thick Si-composite electrodes by the evaporation method may be problematic since Li can only be deposited on the surface of the electrode, but not throughout the depth of the electrode.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer remarked that both the calendar and cycle life performance are still under target. The reviewer recommended more understanding on the degradation mechanisms.

Reviewer 2

The reviewer observed that it is as planned.

Reviewer 3

The reviewer claimed that the generating of materials reproducibly using a scalable process is an important milestone achievement. The reviewer suggested that more work may be needed to develop the binder, where the use of bitumen may be problematic without tighter property specifications. The reviewer added that understanding electrode surface phenomena, including the surface wettability, may present significant opportunities with regard to the electrode performance, particularly at high load. The reviewer noted that this may be an area where a focused study of trace additives may be useful.

Reviewer 4

The reviewer said that milling single crystal ingots to form Si nanoparticles seems to be an expensive route since it is already expensive to form these single crystal boules. The reviewer recommended that the team should perhaps mill low-cost Si polycrystals to form Si nano-particles for Li-ion battery applications.

Reviewer 5

The reviewer expressed that the results show good progress into understanding the failure mechanism in high energy anodes. The reviewer added that scalability is achieved but the performance optimization is the critical next step. The reviewer noted that the team approach to understanding the mechanism in each different manufacturing process is critical in understanding the effect of electrode manufacturing in anode performance.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer observed that there is outstanding collaboration between the various teams in the program.

Reviewer 2

The reviewer mentioned that the collaboration between several national labs and universities seems to be efficient.

Reviewer 3

The reviewer commented that the collaboration across EERE and universities is outstanding, but that more industry engagement is desirable for technology transfer.

Reviewer 4

The reviewer stated that there is great collaboration among national labs, but that it would be very beneficial to have some industrial collaborations.

Reviewer 5

The reviewer remarked that the collaborations are mainly within several National Labs. The reviewer suggested that expanding collaborations to include experts on mechanical characterization may be helpful to the overall project goals, such as high loading Si-electrodes.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer claimed that future research will be helpful to the broader research community on a fundamental level. The reviewer added that steady progress toward the targets for electrode cycle life and capacity indicates a high probability of success.

Reviewer 2

The reviewer remarked that future work planned in this project is critical towards this process being commercialized.

Reviewer 3

The reviewer mentioned that processing (mixing/coating) is very critical for good electrode performance, especially for thick electrodes, and it should be the main focus. The cell density of 400Wh/kg for Silicon cells seems too high for the reviewer and needs to be justified.

Reviewer 4

The reviewer observed that overcoming mechanical degradation may be challenging.

Reviewer 5

The reviewer declared that a more detailed plan should be described.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer noted that this work is of fundamental relevance to the battery program, as Si electrodes will be an important development in commercialization of automotive cells.

Reviewer 2

The reviewer remarked that Si is a very promising anode candidate for high energy batteries, such as for EVs.

Reviewer 3

The reviewer expressed that the project supports the VTO battery objectives.

Reviewer 4

The reviewer observed that the project is very much relevant as Si based anode will open the battery industry to achieve higher energy utilization as a complete product.

Reviewer 5

The reviewer claimed that the program does support the VTO subprogram objects, and that it also addressed the issues in a promising way.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer claimed the resources are sufficient.

Reviewer 2

The reviewer commented that the resources allocated to the project are sufficient to achieve its stated goals.

Reviewer 3

The reviewer made no comments.

Reviewer 4

The reviewer declared that although the team has sufficient resources, it may consider collaborations with experts on mechanical property characterizations.

Reviewer 5

The reviewer stated that while progress toward the project goals is outstanding, more resources are needed in this area for a broader impact on manufacturability of advanced electrode materials.

Presentation Number: bat501
Presentation Title: Integrated Modeling and Machine Learning of Solid-Electrolyte Interface Reactions of the Silicon Anode
Principal Investigator: Kristin Persson, Lawrence Berkeley National Laboratory

Presenter

Kristin Persson, LBNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

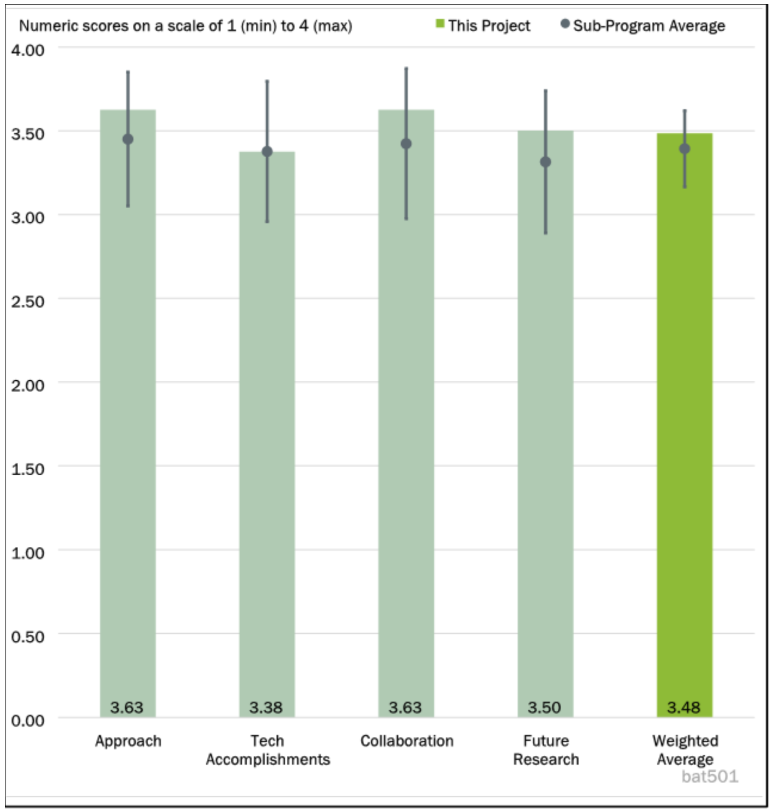

Figure 2-16 - Presentation Number: bat501 Presentation Title: Integrated Modeling and Machine Learning of Solid-Electrolyte Interface Reactions of the Silicon Anode Principal Investigator: Kristin Persson, Lawrence Berkeley National Laboratory

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer noted that the project is well designed and the timeline is reasonable.

Reviewer 2

The reviewer mentioned that the approach seems to be comprehensive, bridging multiple length and time scales to simulate SEI dynamics.

Reviewer 3

The reviewer claimed that the atomistic simulation to understand the mechanism of SEI formation on Si anode is critical to develop the material for commercial application.

Reviewer 4

The reviewer remarked that the modeling work provides a fundamental understanding about the SEI formation which is one of the most important degradation factors for Si anodes.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer stated that the accomplishments demonstrated by the team show the various approaches taken by the team to understand the mechanism.

Reviewer 2

The reviewer said it is as planned.

Reviewer 3

The reviewer noted that the team is able to model SEI growth without any fitting parameters, capture depth-dependent SEI species, and validate voltage-hold experiments. The reviewer hoped that specific predictions from the multiscale modeling effect will soon help guide the overall project to achieve the required calendar and cycle life of Si-electrodes.

Reviewer 4

The reviewer expressed that some interesting findings were revealed through the modeling work. The reviewer added that the correlation between the failure mechanism and findings is still required.

Question 3: Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1

The reviewer noted the excellent collaborations.

Reviewer 2

The reviewer remarked that the National Labs and university collaborations seem effective.

Reviewer 3

The reviewer observed outstanding collaboration between the various teams in the program.

Reviewer 4

The reviewer commented that great team work has been demonstrated to put all the understanding together.

Question 4: Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1

The reviewer commented that if great team work continues, clearer understanding about Si SEI is more likely to be achieved.

Reviewer 2

The reviewer noted that future work is clearly defined, and that the team is very capable on characterization. The reviewer asked if the team planned to validate the reactions/mechanisms found in simulation by experiments.

Reviewer 3

The reviewer stated that in addition to helping understand what is known about the SEI, the team may aim at making predictions based on the validated models to help develop more stable SEIs.

Reviewer 4

The reviewer mentioned that more future work is needed in building the relationship between the calendar aging mechanism and the science behind the failure modes.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer remarked that Si is a very promising anode candidate for high energy batteries, such as for EVs.

Reviewer 2

The reviewer noted that the project supports the VTO battery objectives.

Reviewer 3

The reviewer expressed that the project is very much relevant as Si-based anode will open the battery industry to achieve higher energy utilization as a complete product.

Reviewer 4

The reviewer said yes, the project supports the VTO subprogram objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated that the resources are sufficient.

Reviewer 2

The reviewer said that the team seems to have sufficient resources.

Reviewer 3

The reviewer remarked that the resources allocated to the project are sufficient to achieve its stated goals.

Reviewer 4

The reviewer made no comments.

Presentation Number: bat523
Presentation Title: Development of Long Life Lithium and sulfurized polyacrylonitrile (SPAN) Cells
Principal Investigator: Ping Liu, University of California-San Diego

Presenter

Ping Liu, University of California-San Diego

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

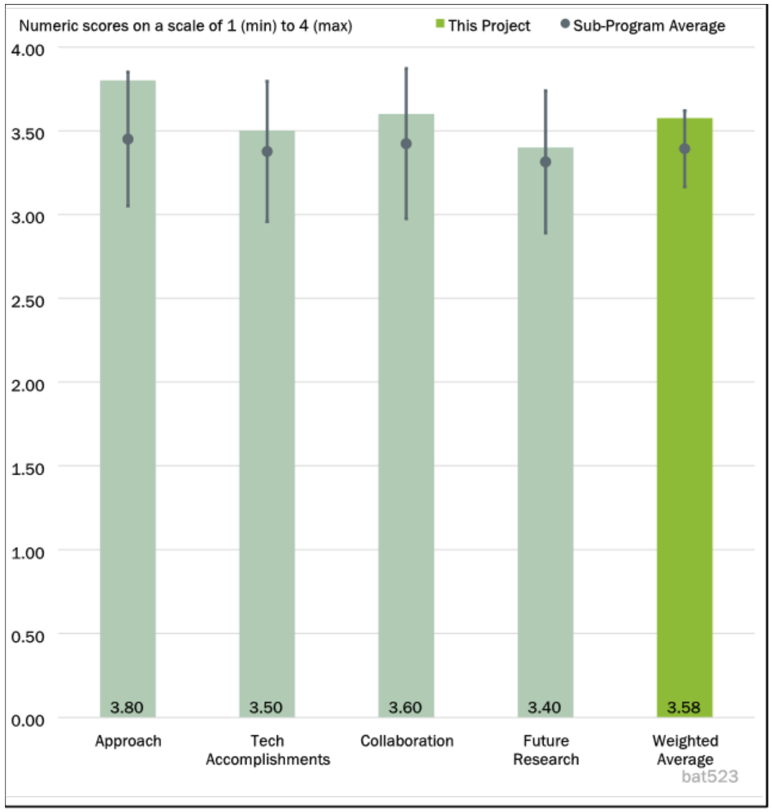

Figure 2-17 - Presentation Number: bat523 Presentation Title: Development of Long Life Lithium and sulfurized polyacrylonitrile (SPAN) Cells Principal Investigator: Ping Liu, University of California-San Diego

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer expressed that Dr. Liu and team perform world class research.

Reviewer 2

The reviewer stated that the roadmap of this research showed that the SPAN cathode is promising but further improvement in capacity is needed. The reviewer added that the project is, so far, well designed when it comes to the fundamental understanding of the research and the timeline is reasonably planned.

Reviewer 3

The reviewer stated that the project addresses the two key technical barriers of current EV batteries, which are low specific energy and high cost; improvements in these two categories are the objectives of the Battery500 program, to which the current project belongs. The reviewer added that lithium-sulfur chemistry is in principle well suited to meet these performance targets but is deterred by the enormous challenge from the polysulfide intermediates that dissolve in most of the organic electrolytes. The reviewer noted that while another project is aiming to mitigate the polysulfide challenge, this project is developing a stable, low-cost alternative to S-C composites based on sulfurized polymer, especially sulfurized-polyacrylonitrile (SPAN). The reviewer remarked that this material has been well studied in literature and has been shown to cycle well but with specific capacity (1.5 mAh/cm^2). The reviewer expressed that accordingly, the targeted specific energy is lowered to 300 Wh/kg. The reviewer concluded that there is noticeable compromise in performance vs. the Battery500 target. The reviewer said that specific energy demonstrated in Phase I is below 300 Wh/kg (265 Wh/kg), but good cycle life was demonstrated with a new electrolyte. The reviewer commented that this year's effort has focused on the first cycle irreversible transformation for the SPAN cathode with much lower discharge voltage. The reviewer affirmed that overall, the approach looks reasonable but only partly contributes to overcoming the barriers of Li-S chemistry, unless the capacity is improved with new polymers. The reviewer listed two weaknesses as being: i) Even though the cycle life is improved significantly compared to conventional Li-S cells, the specific capacity of the cathode and hence the specific energy of the cells are significantly lower. The specific energy realized in 2 Ah cells was only 265 Wh/kg, just about the same as the current Li-ion cells. ii) It is difficult to improve the capacity with new sulfurized polymers; this project should have been the topic of study, probably more than the first cycle irreversible transformation of SPAN.

Reviewer 4

The reviewer noted that LiS rechargeable battery is a very challenging chemistry to realize. The reviewer said that however, there is a huge commercial potential for this chemistry to be used not only for EV, but also for stationary energy storage and aviation energy storage. The reviewer explained that in particular, the sulfur cathode materials dissolution in the electrolyte during electrochemical process is a critical technical barrier to be solved. The reviewer added that the proposed work is focused on preventing/managing polysulfides dissolution, the major technical barrier for LiS battery chemistry. The reviewer expressed that the project develops LiSPAN composite structures to manage polysulfides dissolution during the electrochemical process. The reviewer observed that the project objectives include developing next generation high-energy, low-cost batteries for electric vehicles, designing, fabricating and validating high energy pouch cells up to 500 Wh/kg, scaling up pouch cell capacity to 5-10 Ah, demonstrating long cycle life of up to 1,000 deep charge-discharge cycles, and achieving total control of battery chemistries for robust, scalable and commercially viable cells based on the LiSPAN LiS technologies. The reviewer claimed that SPAN is proposed as a stable, low-cost alternative to S-C composites, and that although Roadmap shows SPAN's promise but further improvement in capacity is needed. The reviewer stated that as of today, developing synthetic approaches for SPAN and alternate polymers is being explored by the PI's team. The reviewer declared that the SPAN composite approach to manage polysulfide dissolution has demonstrated initial success supported by earlier literature and research works. The reviewer concluded that the project is well designed and the timeline to achieve the program goal is reasonable.

Reviewer 5

The reviewer said that the PIs tried to understand the mechanism of the redox reaction of SPAN, which is an active area of research for the polymeric sulfur cathode. The reviewer claimed that one of the barriers of Li-S battery is the so-called shuttle effect which resulted from the high dissolution of polysulfide ions. The reviewer added that the polymeric sulfur materials like SPAN can restrain the sulfide on the polymer backbone. The reviewer expressed that by means of both electrochemical cycling and advanced analytical tools, the PIs proposed a mechanism of SPAN redox reaction. The reviewer recommended that the PIs should focus on if the proposed mechanism can explain the higher discharge capacity than the theoretical capacity based on sulfur, i.e., something else along with sulfur contributing to charges.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer remarked that excellent progress has been made in the demonstration of laboratory scale synthesis of SPAN material and its performance of 265 Wh/kg in 2 Ah pouch with new electrolyte. The reviewer was not sure if its cycle life is as long as shown in the top-left figure on the slide. The reviewer added that during this review period, the first cycle life irreversible transformation was addressed using several techniques. The reviewer stated that the results indicate that the cathode (SPAN) loses both hydrogen and sulfur from non-aromatic cleavages contributing capacity loss and the C=S bonds are irreversibly transformed but contribute to reversible capacity subsequently. The reviewer remarked that interestingly, SPAN becomes more conducting with improved conjugation, which explains the increase in the discharge voltage. The reviewer claimed that these studies may help design new sulfurized polymers with higher capacities. It was not clear to the reviewer how Li anode performed as well for that many cycles. the reviewer asked if it is a protected Li anode. The reviewer questioned how much excess Li was used here (N/P). The reviewer recommended that there should have been some effort to identify new higher-capacity sulfurized polymers. The reviewer asked if the sulfur content can be increased at all. The reviewer noted that some design study is needed to verify if high specific energies beyond Li-ion batteries are possible with the SPAN-like cathodes having low capacity, lower cell voltage and poor conductivity (requiring higher proportion of conductive diluent).

Reviewer 2

The reviewer observed very good progress in reducing the ICL of these promising SPAN materials. The reviewer added that the 2Ah pouch cell at 265Wh/kg is very promising. The reviewer noted that although we expect Li/S cells to be much higher, the goal for commercialization is likely going to be "as good or better" as the cost advantage should be very high.

Reviewer 3

The reviewer noted that this project started in late 2021, and that the PI's team has successfully identified first cycle mechanism loss of hydrogen and S by the formation of H_2S, limited sulfur separation in the materials, the presence of C-S bond in non-aromatic structures, and irreversible loss of C-S and formation of S_2- during the first cycle. The reviewer remarked that considering the project is in its initial stage of 13% in progress, the progresses made by the PI's team have been excellent.

Reviewer 4

The reviewer expressed that the PIs reported a 1 Ah pouch cell based on SPAN cathode, and that the PIs reported that the difference of the first cycle of a SPAN cathode was due to the formation of H_2S from the gap S. The reviewer added that limited S separation after the first cycle was also reported. The reviewer declared that the major accomplishment was the new electrolyte which can improve the performance of SPAN. The reviewer recommended that the PIs check the S distribution after multi-cycles, and take into consideration if the H_2S formation was from gap S or just the residual elemental S remaining during the synthesis.

Reviewer 5

The reviewer commented that the research group performed a comprehensive study to understand the first cycle irreversible transformation for the SPAN cathode. The reviewer listed that they found a loss of hydrogen and sulfur in the form of H_2S; the SPAN cathode becoming more conducting with improved conjugation; and the C=S bond irreversibly transformed but subsequently contributing to reversible capacity. The reviewer added that the understandings achieved are expected to help the follow-on studies to further improve the SPAN as a cathode material for Li-S batteries. The reviewer suggested that the group, however, should investigate the reproducibility of these materials and cells.

Question 3: Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1

The reviewer observed no issues.

Reviewer 2

The reviewer claimed that this is a Battery500 project with broad collaboration with national labs, universities, and industry. The reviewer added that in particular, the PI is working with INL on SPA synthesis transferring, PNNL and University of Maryland, Pennsylvania State, and University Pittsburgh on supplying standard SPAN electrode, Stanford University on evaluating electrolyte, Brookhaven National Laboratory (BNL) on the mechanism study, and Texas A&M on computational study.

Reviewer 3

The reviewer expressed that as part of the Battery500 Consortium, the PIs were well integrated into the team of PIs which include those from national labs and industries.

Reviewer 4

The reviewer commented that the research has been deployed in close collaboration with national labs toward the fundamental understandings, but not with industries yet. The reviewer recommended that industry collaboration is needed in the future.

Reviewer 5

The reviewer stated that there are several ongoing collaborations with the DOE Battery500 team members, which are well detailed. The reviewer clarified that, for example, they collaborated with Idaho National Laboratory for SPAN synthesis scale up, Pacific Northwest National Laboratory and University of Maryland, Pennsylvania State University and University of Pittsburgh for the SPAN electrodes, Stanford University for evaluating electrolytes, BNL for mechanistic studies using in-situ XRD and PDF, and Texas A&M University for computational study of SPAN structures. The reviewer recommended that more active collaboration with GM and possibly an industrial partner (Li-S company) will be beneficial to demonstrate the SPAN comprehensively in more representative prototype cells.

Question 4: Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1

The reviewer claimed that even though the preliminary results are encouraging from a cycle life perspective, there is a serious question on how to raise S loading without affecting the reversibility (cycle life) and how to ensure good cycle life with a Li anode at high current densities required against dense cathodes. The reviewer added that the proposed future study is aimed to address these questions. The reviewer explained that specifically, the proposed study will focus on how to tune chemical synthesis conditions, raise reversible S content by compositing SPAN and S and identify compatible electrolytes especially for Li/SPAN cells with lean electrolyte.

Reviewer 2

The reviewer believed this team is considering a SPAN/S composite cathode. The reviewer observed that the issue is that the two function best with different electrolyte classes. The reviewer did not see cell Wh/kg as necessarily a showstopper here and it seemed like SPAN might be good enough. The reviewer recommended that if it is not, an investigation into re-engineering the SPAN material to enhance the S content might be valuable.

Reviewer 3

The reviewer declared that the project is centered at using SPAN composites to confine/manage polysulfides dissolution during the electrochemical operation of the sulfur cathode electrode. The reviewer noted that future work is focused on fully understanding the mechanism of the SPAN materials during the electrochemical process, and developing SPAN materials composition to evaluate the effectiveness of polysulfides management by this class of composite materials. The reviewer articulated that future work also investigates the impact of the materials to the battery performance such as loading and impacts to lithium metal electrode.

Reviewer 4

The reviewer stated that the PIs clearly defined the future work, which was based on the current achievements and in alliance with the overall Battery500 goals. The reviewer added that in the literature, it has been widely reported that there is an optimal S loading in a SPAN, raising S loading beyond the value will have a negative impact on the SPAN cathode. The reviewer asked the team to address how raising S loading can increase capacity while maintaining reversibility.

Reviewer 5

The reviewer stated that yes, the purpose of future work has been clearly defined. The reviewer added that the detailed approaches are not provided. The reviewer asked what approaches will be taken to reduce the capacity loss, and what structures of the SPAN electrode will be developed.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer stated that the project supports the overall DOE objectives by overcoming the deterrents of low specific energy and high cost of current Li-ion cells, with a new system involving Li anode and SPAN cathode. The reviewer added that even though the benefits are not significant to approach 500 Wh/kg, there has been a marginal increase in specific energy, which can be further improved with new S-polymer. The reviewer observed that the stated goals of demonstrating high specific energy (goal: 500 Wh/kg) and long cycle life (1000 cycles) in pouch cells of 5-10 Ah are consistent with the DOE goals. The reviewer concluded that, overall, this project is quite relevant to the DOE VTO battery program objectives and goals.

Reviewer 2

The reviewer declared that it is highly relevant given the abundance and affordability of sulfur, and that this is critical research for enablement of wide scale EV adoption.

Reviewer 3

The reviewer expressed that this project is highly relevant to the battery storage subprogram, as the success of this project leads to significant reduction of both battery cost and the use of critical materials.

Reviewer 4

The reviewer remarked that Li-S batteries are considered as one of the most promising chemistries to replace Li-ion batteries in transportation. The reviewer added that investigating polymeric sulfur cathode supports the overall VTO objectives.

Reviewer 5

The reviewer said that yes, the project supports the overall VTO objective in battery analysis, energy density enhancement, and materials development.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer remarked that resources for the overall Battery500 project are commensurate with the scope adequate to achieve the targeted milestones. The reviewer added that the budget details for this specific project haven't been provided.

Reviewer 2

The reviewer observed no issues.

Reviewer 3

The reviewer declared that the resources and project timeline are well aligned.

Reviewer 4

The reviewer stated that Battery500 includes national labs and multiple research universities, and that it can provide more than adequate resources to the proposed research.

Reviewer 5

The reviewer expressed that the research group has necessary facilities and equipment/instrumentation at UCSD. and that the external collaborators listed are supposed to provide necessary support.

Presentation Number: bat524
Presentation Title: Advanced Electrolytes for Lithium Metal Batteries
Principal Investigator: Chunsheng Wang, University of Maryland

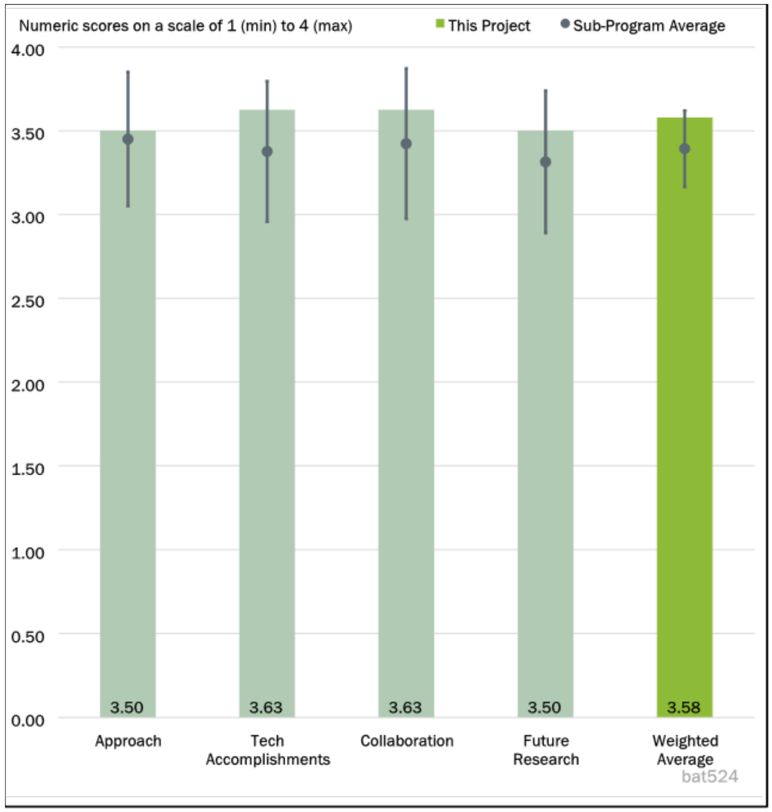

Figure 2-18 - Presentation Number: bat524 Presentation Title: Advanced Electrolytes for Lithium Metal Batteries Principal Investigator: Chunsheng Wang, University of Maryland

Presenter

Chunsheng Wang, University of Maryland

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 50% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer claimed that the University of Maryland team concentrates on novel electrolyte development and has achieved noticeable progress.

Reviewer 2

The reviewer declared that the effort to use lithium-fluoride (LiF) as an SEI on Li does not consider the impact of grain boundaries in the LiF, in which case the properties of pure LiF are not as important. The reviewer added that using LiF for CEI for mechanical reasons looks like a better idea. The reviewer expressed that using an ionic liquid can solve a lot of problems, but it’s not clear that this is a useful approach, both because of cost and because of viscosity problems. The reviewer remarked that fluorinated carbonates have already been widely studied.

Reviewer 3

The reviewer stated that this project is well designed, the timeline is reasonable, and they have already made great progress in fluorinated electrolyte and solvent-free ionic liquid electrolyte. The reviewer noted that there have already been three publications involving this work, the reviewer assumed that much of it was already done prior to the funding of this project.

Reviewer 4

The reviewer articulated that this project proposes to stabilize the interface of Li metal and high-energy cathodes such as NMC and Sulfur through modification of electrolyte structures and formulations. The reviewer remarked that electrolytes are for sure a critical component in forming different SEI/CEI. The reviewer affirmed that the team has studied the formation mechanism of SEI/CEI well, and developed several classes of electrolytes, achieving excellent results.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer claimed that the University of Maryland team accomplished two milestones in Fiscal Year 2022 (FY 2022). The reviewer added that they developed ionic liquid additives that form a LiF-rich SEI that enables greater than 85% capacity retention after 200 cycles for an NMC811 Li cell, and a solvent-free ionic liquid electrolyte demonstrating 80% capacity retention at the 330 cycle for anode-free NMC811 Cu cells. The reviewer remarked that this result is quite impressive as compared to the performance of anode-free NMC811 cells with other electrolytes from the Journal of The Electrochemical Society, 2021 168 120508.

Reviewer 2

The reviewer articulated that fluorinated solvents create an improvement, but that few details are given on how to understand the results. The reviewer added that CE is 99.9% with ionic liquid, but capacity falls with time. The reviewer stated that there was no explanation for why the capacity is falling. The reviewer observed that very flat Li metal surfaces are a major achievement, but that there was no real discussion of how to make ionic liquids practical.

Reviewer 3

The reviewer noted that this work addresses some key issues with lithium metal batteries including solvent-free electrolyte and lithium metal cathode as well as its surrounding issues including low temperature conductivity and dendritic formation.

Reviewer 4

The reviewer commented that the team has developed two generations of electrolytes including fluorinated carbonate electrolytes for Li/S batteries, and solvent-free ionic liquid electrolytes for Li metal and NMC cathode. The reviewer added that both these two electrolytes have led to significantly improved cycle stability not only in coin cells with high loading, but also in practical pouch cells.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer remarked that the team has effective collaborations with universities, national labs, and industrial companies, and that the contribution of each collaborator is clearly indicated.

Reviewer 2

The reviewer observed that the collaboration within Battery500 is excellent.

Reviewer 3

The reviewer noted great collaboration between national labs, universities, battery suppliers and original equipment manufacturers (OEMs).

Reviewer 4

The reviewer stated that the team at the University of Maryland has collaborated well with other Battery500 consortium teams in the testing of cathodes/Li metal anode using their electrolytes.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer claimed that future research is clearly defined with target performance specified.

Reviewer 2

The reviewer was unclear that ionic liquids is a useful path forward, but remarked that studying why the PI observes such flat surfaces is very important.

Reviewer 3

The reviewer noted a lack in specific detail on operating temperature range. The reviewer added that the cycle should target 1000 cycles.

Reviewer 4

The reviewer stated that one of the critical problems for ionic liquid electrolytes is their high viscosity. The reviewer added that the team has proposed to use fluoro-antisolvent to reduce the viscosity and further enhance the cycling and calendaring performance under lean electrolytes. The reviewer declared that one of the critical barriers would be also fast-charging capability, and that it should be addressed particularly in high-viscosity electrolytes and thick electrodes.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer expressed that this project is an important part of Battery500 and contributes greatly to the VTO objective on vehicle electrification.

Reviewer 2

The reviewer observed that the goals are very appropriate.

Reviewer 3

The reviewer remarked that this supports the VTO objective of increasing battery energy density, improving cycle life, as well as increasing safety/reducing toxicity with no solvent electrolyte.

Reviewer 4

The reviewer commented that electrolytes developed by the University of Maryland team would for sure play a critical role in enabling 500Wh/kg and 1000 cycle batteries that VTO is targeting.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer claimed that the team has sufficient resources for their research project.

Reviewer 2

The reviewer declared that it was sufficient.

Reviewer 3

The reviewer expressed that there are significant resources dedicated to this project from both a monetary stand point as well as personnel.

Reviewer 4

The reviewer commented that the team led by Professor Wang is a world-leading group in electrolyte development for various batteries systems.

Presentation Number: bat525
Presentation Title: Fluorinated Solvent-Based Electrolytes for Low Temperature Lithium-ion Battery
Principal Investigator: John Zhang, Argonne National Laboratory

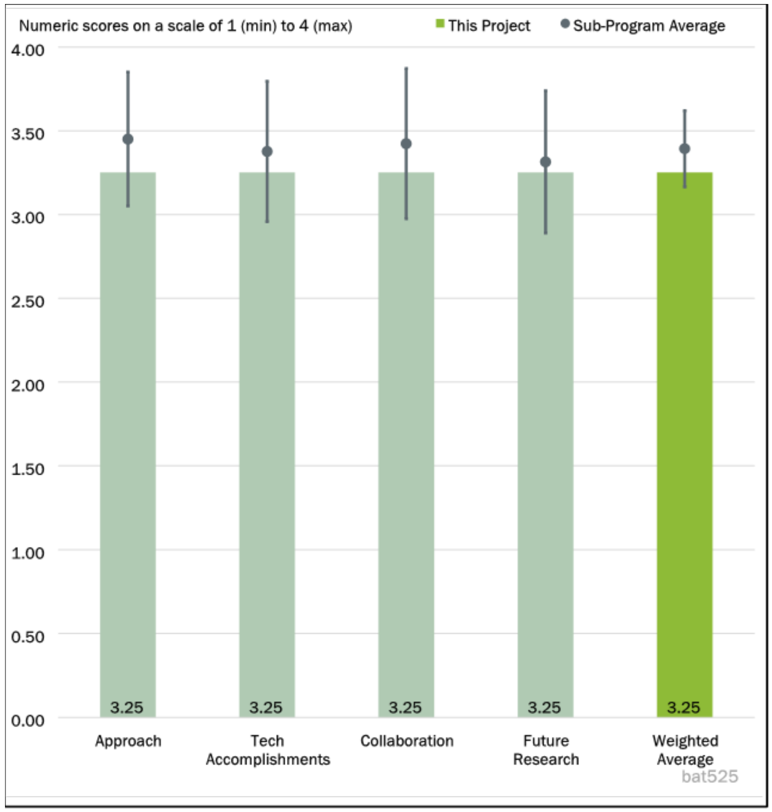

Figure 2-19 - Presentation Number: bat525 Presentation Title: Fluorinated Solvent-Based Electrolytes for Low Temperature Lithium-ion Battery Principal Investigator: John Zhang, Argonne National Laboratory

Presenter

John Zhang, ANL

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer stated that the presentation quality is high, and it was well presented during AMR. The reviewer added that there is good rationale and excellent lab techniques. The reviewer observed that overall there was solid progress in obtaining lab results, but some data and explanations on cause and effect are still lacking on the modeling side.

Reviewer 2

The reviewer remarked that guided by modeling [DFT and MD), they designed and developed well-known fluorinated electrolytes for low-temperature performance.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer stated that low-temperature (LT) improvements of best systems discovered by this work meet program objectives in relation to the second-generation electrolyte, but that they are still modest and require further work to improve the lifecycle stability. The reviewer asked if the fluorinated compounds are prohibitively expensive. The reviewer mentioned that the proportion of FEC is still high (10%) compared to typical loadings seen elsewhere (less than 5%). The reviewer added that increased contact-ion pairs (CIP) in electrolytes with fluorinated solvents is problematic both for electrolyte conductivity and for breaking the energy of CIP ion association. The reviewer noted that this is a trade-off with potentially lower de-solvation energies that the fluorinated esters may provide. The reviewer remarked that there is no mention of the underlying cause behind why the CIP species are more prevalent under these conditions. The reviewer explained that this is likely due to lower permittivity of the fluorinated solvents. The reviewer concluded that the lowered de-solvation energies are claimed, but that no actual comparisons were given, especially over the number of ligands that would comprise a fully solvate lithium ion. The reviewer questioned if the solvent residence times have been validated against data, such as NMR bandwidth studies.

Reviewer 2

The reviewer claimed that they developed fluorinated ester for good LT electrolyte. The reviewer added that they developed good understanding of the Li^+ solvation and impact of SEI and charge transfer on LT performance. The reviewer observed that their improved LT performance was in a cell with low loading of 1.7mAh/cm^2.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer claimed that specific collaboration tasks with industry (Navitas, NOHMs) were not clear.

Reviewer 2

The reviewer observed that they collaborated with industry, Army Research Laboratory, and national labs.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer remarked the good set of goals that hopefully will be achieved by close of project this September.

Reviewer 2

The reviewer suggested that they need to carry out the proposed future research in a cell with more practical loading of 3 mAh/cm^2 or higher.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer stated that there is good alignment with VTO objectives.

Reviewer 2

The reviewer claimed that the effort met VTO's program objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer remarked that the resources are adequate given the teaming and research plan.

Reviewer 2

The reviewer observed that funding is sufficient.

Presentation Number: bat526
Presentation Title: Ethylene Carbonate-lean Electrolytes for Low Temperature, Safe Lithium-ion Batteries
Principal Investigator: Bryan McCloskey, Lawrence Berkeley National Laboratory

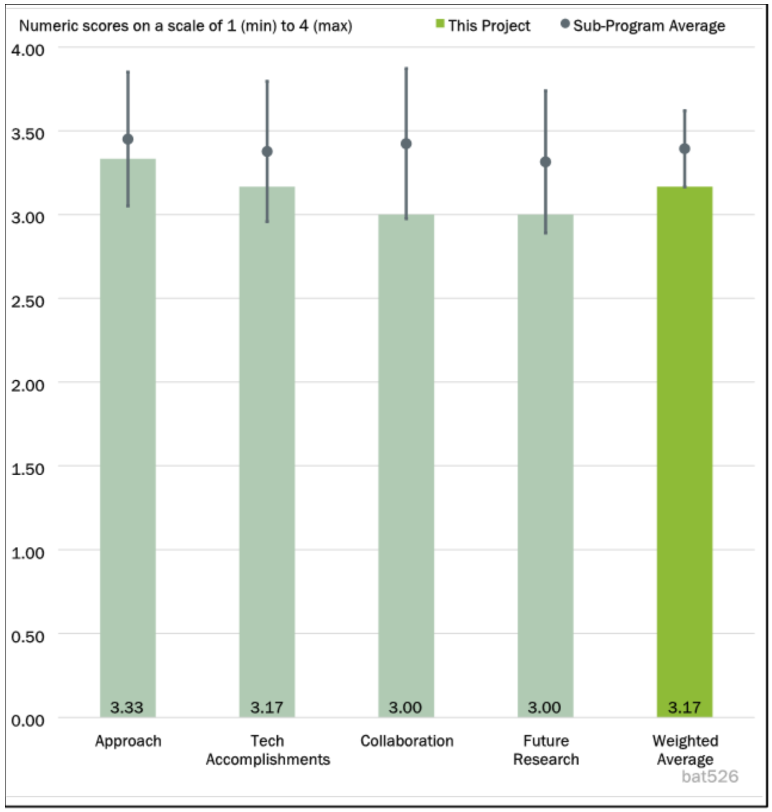

Figure 2-20 - Presentation Number: bat526 Presentation Title: Ethylene Carbonate-lean Electrolytes for Low Temperature, Safe Lithium-ion Batteries Principal Investigator: Bryan McCloskey, Lawrence Berkeley National Laboratory

Presenter

Bryan McCloskey, LBNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer observed that cold temperature performance is a critical area for progress, and the approach using co-solvents shows some initial promise. The reviewer added that coordinating this effort to a greater extent with research on Si electrodes is needed.

Reviewer 2

The reviewer stated that this was a clear presentation, and was easy to follow. The reviewer thanked the presenter. The reviewer added that the team has a good lab approach that helps isolate LT terms of interest.

Reviewer 3

The reviewer commented that they adopted a well-known approach for good LT electrolyte by replacing the high melting point solvent, ethylene carbonate (EC).

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer noted that the effects at cold temperature following cyclic aging would be more informative in understanding the potential for commercial applications, as the SEI layer effect is a critical element of this research.

Reviewer 2

The reviewer appreciated the electrode-wise evaluations. The reviewer added that the γ-butyrolactone (GBL) work seems overemphasized, as there are other routes to replace EC with stable viscosity-reducing compounds that will maintain acceptable free ion populations. The reviewer noted that on Slide 11, this is a newer technique with somewhat controversial or puzzling outcomes such as zero or negative t^+ values. The reviewer claimed that this team should provide a rationale for why the trends and magnitudes are as they appear, and why this differs from traditional electrochemical methods, probably relating to a paper or two from Balsara. The reviewer asked the team to also include those citations. The reviewer affirmed that the team correctly asserts that R_{CT} dominates cycling performance at low temperature, and that this is shown to be due more on the anode side. The reviewer claimed that they stop short at providing a mechanistic explanation for this. The reviewer commented that the A1 additive provides modest improvement to get just above 70% capacity at −20°C, C/3 rate. The reviewer also suggested that the team should consider other common-sense co-solvents to reduce viscosity, such as low molecular weight esters and fluorinated variants. The reviewer declared that even small amounts (10%–20%) can have a noteworthy improvement in capacity delivery at LT. The reviewer concluded that this project taken as a whole, has a high quality of work, but recommended that more electrolyte systems could have been considered, screened and tested to arrive at a richer field of options.

Reviewer 3

The reviewer stated that they were unsuccessful in replacing EC with GBL but developed good understanding of the impact of charge transfer resistance on LT performance. The reviewer added that they developed an additive that resulted in better LT performance in a NMC622/graphite cell than the baseline second generation electrolyte. The reviewer noted that the performance difference in Slide 14 might not be statistically significant.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer commented that greater collaboration with materials development in EERE would strengthen the relevance of this activity.

Reviewer 2

The reviewer noted that the collaboration appears to be primarily within Lawrence Berkeley National Laboratory (LBNL), with support on materials from Argonne National Laboratory (ANL). The reviewer observed that there was no mention of collaboration with industry. The reviewer suggested that they should consider expanding collaboration either with other DOE labs, universities and/or with industry.

Reviewer 3

The reviewer observed that they collaborated with LBNL and Cell Analysis, Modeling, and Prototyping Facility (CAMP) at ANL.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer claimed that the project is nearly complete, and will likely meet the project deliverables. The reviewer stated that extending this work to future electrode materials would be interesting.

Reviewer 2

The reviewer noted that the suggested future work has reasonable targets, but they are few and quite limited in scope.

Reviewer 3

The reviewer suggested that in addition to the proposed future work, they should also characterize the impact of the A1 additive on high-temperature performance.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer observed that this work is of fundamental relevance to the battery program, as improved cold temperature performance is needed for nationwide adoption of EVs.

Reviewer 2

The reviewer noted that there is good alignment with VTO objectives.

Reviewer 3

The reviewer claimed that the work met the VTO program objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer claimed that looking at the project as it nears completion, the resources appear to have been adequate for a successful study of low-temperature electrolytes.

Reviewer 2

The reviewer observed that the resources are adequate given the teaming and research plan.

Reviewer 3

The reviewer stated that funding is sufficient.

Presentation Number: bat527
Presentation Title: Synthesis, Screening and Characterization of Novel Low Temperature Electrolyte for Lithium-ion Batteries
Principal Investigator: Xiao-Qing Yang, Brookhaven National Laboratory

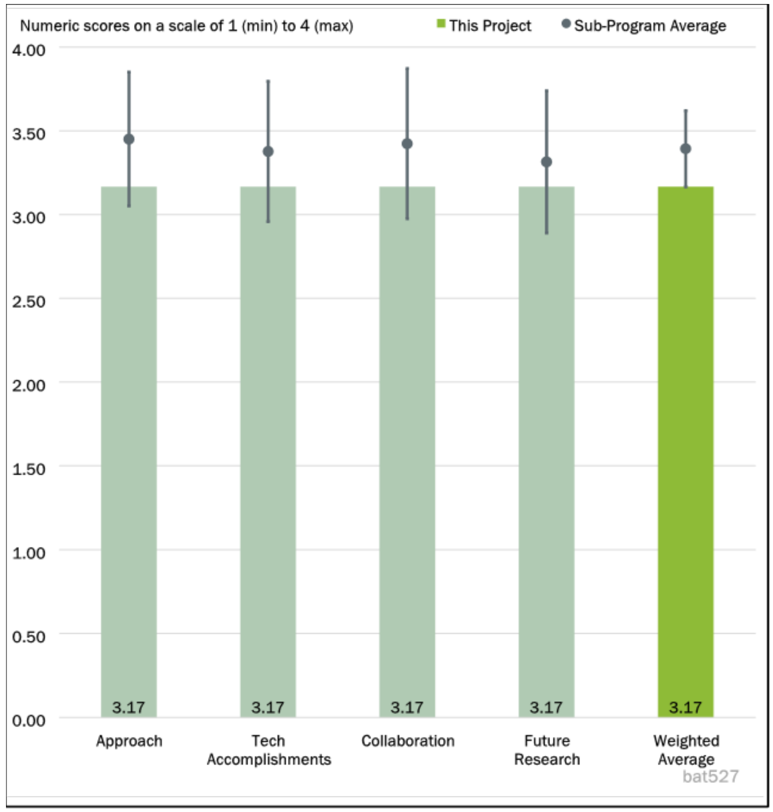

Figure 2-21 - Presentation Number: bat527 Presentation Title: Synthesis, Screening and Characterization of Novel Low Temperature Electrolyte for Lithium-ion Batteries Principal Investigator: Xiao-Qing Yang, Brookhaven National Laboratory

Presenter

Xiao-Qing Yang, BNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer noted that the overall thrust is going in a positive direction. The reviewer observed that the presentation is very wordy and not well organized for review. The reviewer concluded that the contributions from the team members seem disjointed. The reviewer added that the electrolyte design strategy with LHCEs is understood; however, the extent of CIP and SSIP formation is concerning in that very low fractions of "free" lithium ions are projected (less than 0.07) over the temperature range of -60 to 60°C (Slide 16). The reviewer remarked that the team seems particularly keen in publishing and securing patents.

Reviewer 2

The reviewer claimed that this project is nearly complete with a wide scope of electrolytes tested at low temperatures and cathode materials.

Reviewer 3

The reviewer declared that guided by modeling (MD), they relied on a combinatory approach of salt, solvent and additives to achieve good LT performance.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer stated that cycle life is still of concern if it can be brought up to 1000 cycles. The reviewer added that commercial grade cell testing would also be of value.

Reviewer 2

The reviewer remarked that they demonstrated good performance at both RT and LT, using LHCE with different diluents, and in Li/SPAN or NMC811 cells. The reviewer added that most of the data was based on relative low loading of 2.5 mAh/cm^2. The reviewer observed that instead of the plethora of data, they need to focus on demonstrating overall good performance (LT and HT) in one cell chemistry.

Reviewer 3

The reviewer asked what F1, F2, F3…are. The reviewer added that not knowing what these are does not help with evaluation of the technical objectives. The reviewer asked if the fluorinated compounds are prohibitively expensive. The reviewer noted that achievable capacity at LT is obtained at 0.2C cycling rate (Slides 13,14) and 0.1C (Slide 13). The reviewer stated that however, the performance requirement is that the achievable capacity (particularly at -20 C) be determined at a C/3 rate. The reviewer noted that in relation to responses to last year's reviewer comments, one reviewer mentioned the thermodynamics of electrolyte phase behavior at lower temperatures, wherein there can be electrode surface-driven interactions. The reviewer remarked that the response was "The work done this year followed this suggestion and carried out the thermodynamic studies of electrolyte at low temperatures." The reviewer mentioned that nothing is found in the presentation regarding the thermodynamics of electrolyte phase behavior. The reviewer observed that on the Summary slide it states "Improved low temperature performance was obtained when esters (methyl acetate, MA and methyl propionate, MP) are added as co-solvents in the carbonate-based electrolyte formulations." The reviewer noted that these LT results are nowhere to be found in the presentation materials, except for scant mention on Slide 10. The reviewer concluded that there was a mixed message on anodes used in the work with graphite mentioned in some places while lithium metal is also mentioned (Slides 8,9). The reviewer asked what the ultimate focus to meet the LT goals of this project was.

Question 3: Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1

The reviewer claimed that the team had good representation from PIs in each organization, and that there is no mention of industrial collaborators.

Reviewer 2

The reviewer noted the collaboration between several national labs and universities, but stated that they are missing industry partners.

Reviewer 3

The reviewer remarked that BNL collaborated with universities and other national labs.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer noted a good set of goals that hopefully will be achieved by close of project this September.

Reviewer 2

The reviewer observed that the work is mostly done with the exception of publications.

Reviewer 3

The reviewer remarked that the project will be complete by the end of FY 2022.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer claimed that there is good alignment with VTO objectives.

Reviewer 2

The reviewer noted the low temperature battery electrolyte that also has good high temperature performance.

Reviewer 3

The reviewer remarked that the work met VTO program objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer remarked that the resources are adequate given the teaming and research plan.

Reviewer 2

The reviewer expressed that they achieved a great amount of work in a three-year time frame that the project is awarded for.

Reviewer 3

The reviewer affirmed that the funding is sufficient.

Presentation Number: bat528
Presentation Title: Structurally and Electrochemically Stabilized Silicon-rich Anodes for Electric Vehicle Applications
Principal Investigator: Murali Ramasubramanian, Enovix

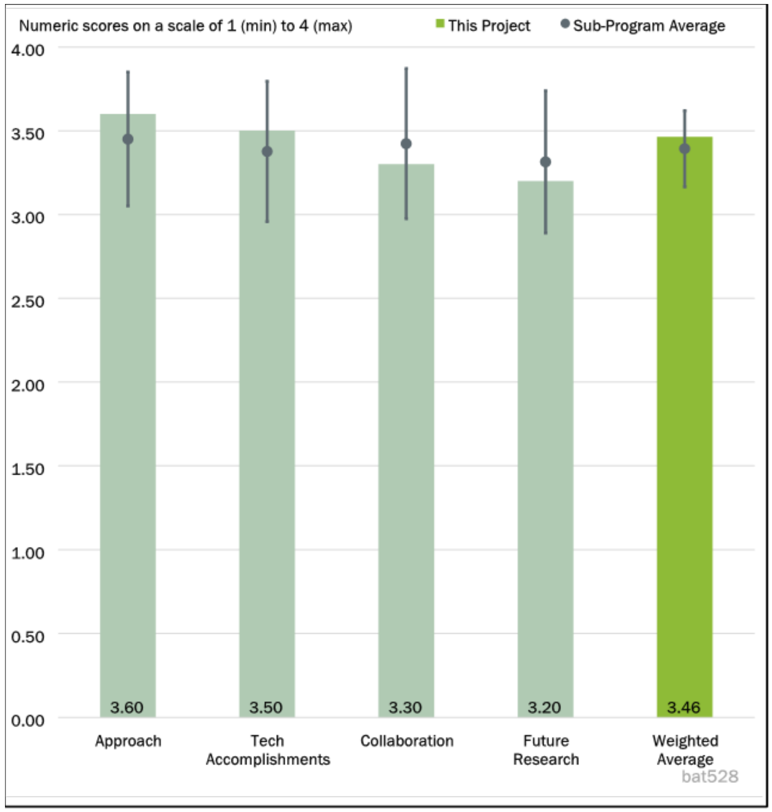

Figure 2-22 - Presentation Number: bat528 Presentation Title: Structurally and Electrochemically Stabilized Silicon-rich Anodes for Electric Vehicle Applications Principal Investigator: Murali Ramasubramanian, Enovix

Presenter

Murali Ramasubramanian, Enovix

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer noted that the Enovix cell design is unique, and that the approach of reorienting the electrodes to more easily apply pressure and allow prelithiation is promising, interesting, and very innovative. The reviewer added that demonstrating that the design can be scaled-up with higher energy density, and that it can be fabricated inexpensively, are the keys to overall success in Year 2.

Reviewer 2

The reviewer commented that the cycle and calendar life of Si anode are the two most prominent problems and the technology seems to provide a good solution.

Reviewer 3

The reviewer noted the very well-designed project, and stated that a lot was accomplished with the time given. The reviewer looked forward to the following year's results. The reviewer remarked that the approach is clearly laid out and well-explained.

Reviewer 4

The reviewer commented that the Enovix architecture and cell design will be illustrated by cycling performance and calendar year in the first year and the scaling up ability (energy density at EV battery sizes) will be confirmed in the second year. The reviewer concluded that the project is well designed with good plans.

Reviewer 5

The reviewer expressed that Enovix proposed oriented electrodes to the small area sides of the cell to contain the pressure from the large Si volume change. The reviewer stated that while it is an innovative technique to mitigate swelling, it is not clear if their technique can be mass produced, especially when pre-lithiation is still needed to reduce first cycle irreversibility loss.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer expressed that the project has demonstrated initial performance (cycle life, calendar life) which is promising and trending to meet targets. The reviewer added that the energy density, however, remains far from the target even when projected into a larger cell size. The reviewer also remarked that the amount of prelithiation is likely critical to the life results. The reviewer claimed that since this amount was not disclosed, it makes it hard to confirm the results are realistic and can be scaled. The reviewer articulated that a more fundamental understanding of the degradation mechanism is necessary and should be pursued.

Reviewer 2

The reviewer commented that great progress has been made in the calendar life performance, but that the electrode loading or packing efficiency still needs to be improved.

Reviewer 3

The reviewer noted the amazing accomplishment, and hoped everything works out.

Reviewer 4

The reviewer declared that the cycling performance is even better than that of the project plan. The reviewer added that the calendar life is also very promising based on the results until now. The reviewer remarked that the model Si porosity and SEI evolution need to be further developed to provide guidance.

Reviewer 5

The reviewer observed that the Enovix cell demonstrated greater than 1000 cycles but in a 200 Wh/kg cell. The reviewer added that the team also demonstrated greater than 9 months of capacity retention at 50C prolonged storage at 100% state of charge (SoC) in the 200 Wh/kg cell. The reviewer claimed that the Enovix cell with Si anode also demonstrated less leakage current than graphite-based cells at 4.2 volt (V), indicative of long calendar life.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer noted that the project team seems to be communicating and collaborating effectively.

Reviewer 2

The reviewer observed that Enovix partnered with the National Renewable Energy Laboratory (NREL) and Mitsubishi Chemical.

Reviewer 3

The reviewer suggested that more mechanism understanding is needed, and that their national lab partner can be helpful for characterization.

Reviewer 4

The reviewer observed that there is a great partnership with NREL and Mitsubishi Chemical Corporation, but that they could possibly partner with OEMs.

Reviewer 5

The reviewer commented that the calendar life estimation and modeling are made by NREL. The reviewer added that they also have collaboration with Mitsubishi Chemical Corporation on the electrolyte designation. The reviewer suggested that more collaboration may be needed on the characterization to demonstrate the mechanism behind it.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer claimed that the unique cell architecture is the enabler for the Si anode in Enovix's design. The reviewer stated that it is not fully clear how this cell can be effectively scaled up and still meet 350 Wh/kg. The reviewer observed that detailing the design details, and electrodes particularly, will significantly increase the energy density and would be helpful. The reviewer expressed that more disclosure and analysis of prelithiation amount is also important. The reviewer concluded that the project needs to demonstrate that this cell architecture can be scaled up to EV relevant size at EV compatible costs.

Reviewer 2

The reviewer stated that improvement in energy density is required.

Reviewer 3

The reviewer looked forward to the following year's results.

Reviewer 4

The reviewer remarked that the future work is well illustrated. The reviewer observed that even though they are demonstrating a cell-size scalability by building greater than 2 Ah cells with high energy goals, it is highly possible that they can achieve the targets based on their results.

Reviewer 5

The reviewer stated that in addition to demonstrating more than 1000 cycles, they should report RT calendar life data projected based on their 45^0C data, if necessary, in cells with more than 350 Wh/kg at higher than

4.3V charge cut-off. The reviewer recommended that they also need to report thickness change at 1000 cycles and at the completion of calendar life in cells with more than 350 Wh/kg in the same cells.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer mentioned that this project is clearly innovative and interesting. The reviewer stated that it is difficult to balance disclosing too much to lose competitive advantage and too little to lose the ability to convey a convincing plan. The reviewer added that right now, however, the approach to ultimately reach the targets in energy density and cost is fuzzy. The reviewer recommended that more details should be provided to ensure the project can be successful and will further the DOE's goals.

Reviewer 2

The reviewer said yes.

Reviewer 3

The reviewer commented that the silicon anode will greatly improve existing battery performance.

Reviewer 4

The reviewer observed that it supports the batteries subprogram objectives.

Reviewer 5

The reviewer noted that the work met the VTO program objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer expressed that a lot of work is being done for the budget.

Reviewer 2

The reviewer stated that the project seems well resourced.

Reviewer 3

The reviewer articulated that the resources including high level cell building, modeling, and electrolyte developing should be sufficient for this project.

Reviewer 4

The reviewer claimed that funding is sufficient.

Reviewer 5

The reviewer made no comments.

Presentation Number: bat529
Presentation Title: Rationally Designed Lithium-Ion Batteries Towards Displacing Internal Combustion Engines
Principal Investigator: Rick Costantino, Group 14 Technologies

Presenter

Rick Costantino, Group 14 Technologies

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

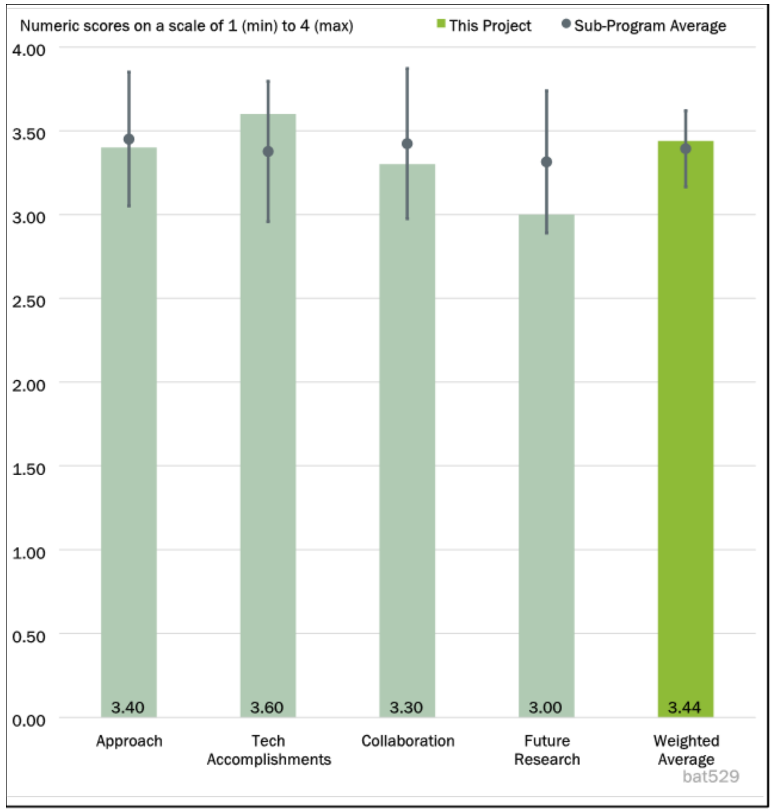

Figure 2-23 - Presentation Number: bat529 Presentation Title: Rationally Designed Lithium-Ion Batteries Towards Displacing Internal Combustion Engines Principal Investigator: Rick Costantino, Group 14 Technologies

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer stated that the first 2 years have shown impressive progress toward developing durable Si electrodes.

Reviewer 2

The reviewer expressed that embedded Si inside a carbon cage seems a pretty effective way to protect the Si particles losing connection from the conductive network which greatly improved the cycle life of Si.

Reviewer 3

The reviewer articulated that the project is well designed. The reviewer noted that the first year has goals to deliver a cell with more than 340 Wh/Kg, more than 300 cycles and more than 3-year calendar life; the second year has goals to deliver the same energy density with more than 600 cycles and more than 5-year calendar life; and the last year has goals to deliver more than 1000 cycles and more than 10-year calendar life. The reviewer observed that the plan is well designed step by step, which makes it very reasonable.

Reviewer 4

The reviewer declared that the team proposed carbon scaffold and designed porosity to mitigate the large volume change of high Si percentage anode using nano Si. Group 14's approach is very similar to the earlier Sila approach.

Reviewer 5

The reviewer claimed that the approach, based on Group 14's unique material, is well sequenced, the timeline looks reasonable, and the performance metrics obtainable. The reviewer added that the material itself, even though limited fundamental information was provided (reporting the particle void volume and showing additional photos would be helpful), addresses the known shortfalls in Si-anode technology. The reviewer remarked that no information was provided on cost, however, which will be a key for eventual market adoption.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer observed that great progress has been made on the cycle life of Si materials.

Reviewer 2

The reviewer stated that advanced characterization of electrode materials will be important going forward, including deeper investigation of surface characteristics, particularly at high load. The reviewer added that the analysis will enable another feedback loop into the process/material improvements.

Reviewer 3

The reviewer claimed that the initial results are encouraging, demonstrating that the material functions reasonably well. The reviewer posed the following questions:

- Does processing differ from typical Li-ion electrodes? Solvent types? Compatible with existing equipment?
- What is the impedance growth? This is a known issue with Si containing anodes and should be shown.
- What is coulombic efficiency?
- Do you understand the degradation mechanism? Understanding why the capacity fades (and likely impedance grows) is likely necessary to significantly increase the life as required for the Phase II and III metrics.
- More details on the "interim" builds would be useful for the community. What specifically was done to improve the cell's performance? Was it all anode conductivity enhancements?
- The reduction in gassing with OS3® additive is encouraging but do you have a gassing target? How much gassing can be allowed?

Reviewer 4

The reviewer expressed that the target on energy density and cycle life have been achieved. The reviewer added that the calendar life is still to be determined, but calendar life data over 9 months looks promising.

Reviewer 5

The reviewer remarked that they demonstrated 350 cycles to 80% capacity retention but it was not clear if the cycle life data was in the reported 340 Wh/kg cell. The reviewer suggested that they should also report thickness change at 350 cycles. The reviewer observed that they reported excellent 45^0C storage for over 9 months at 100% SoC but it was not clear if the excellent 45^0C data was done in the reported 340 Wh/kg cell. The reviewer recommended that they should also report thickness change after 45^0C prolonged storage. The reviewer clarified that they projected more than 800 cycles using modified interim anode design but did not report the energy density or thickness change.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer stated that the material analysis may be an opportunity to expand collaboration with DOE labs.

Reviewer 2

The reviewer claimed that different teams appear to be working well together with adequate communication and planning.

Reviewer 3

The reviewer remarked that great teams are combined in this program and each party has demonstrated significant contribution.

Reviewer 4

The reviewer articulated that Group 14 partnered with well-known industry leaders of components such as electrolyte, binder, and cell maker to demonstrate good performance of their Si anode.

Reviewer 5

The reviewer expressed that they do have many collaborations with other industry and national laboratories, but detailed contributions of them are not so clear. The reviewer added that considering the time needed to do the calendar life test, they may need to collaborate with others on the modeling and prediction of calendar life.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer stated that the description of future work is overly general for a reviewer to offer useful comment, and that progress to date shows success. The reviewer was hopeful that further concentrated effort will yield more positive results.

Reviewer 2

The reviewer expressed that the barriers are clearly identified and the correct focuses are clarified.

Reviewer 3

The reviewer commented that they proposed to further optimize the component of the lithium-silicon and test down-selected combinations to achieve the final project goals. The reviewer added that the target of energy density and cycle life is highly achievable based on their results, but the target on calendar life still requires many efforts.

Reviewer 4

The reviewer remarked that in addition to demonstrating more than 1000 cycles, they should report RT calendar life data projected based on their 45^0C data, if necessary, in cells with greater than 350 Wh/kg at more than 4.3V charge cut-off. The reviewer added that they also need to report thickness change at 1000 cycles and at the completion of calendar life in cells with more than 350 Wh/kg in the same cells.

Reviewer 5

The reviewer claimed that it is not clear from the slides what work will be done to further improve the performance. The reviewer explained that the bullets are too broad and non-specific, and that without additional details it is difficult/impossible to determine the likelihood of success.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer claimed that the project appears to be a significant contribution to commercialization of Si electrodes for automotive applications, of prime relevance to the Battery project area.

Reviewer 2

The reviewer explained that the advanced Si-anodes are clearly relevant and, if successful, can significantly impact the trajectory of EV vehicles in the future.

Reviewer 3

The reviewer said yes.

Reviewer 4

The reviewer claimed that the project supports the batteries as well as the materials objectives.

Reviewer 5

The reviewer expressed that the work met the VTO program objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer noted that the resources appear appropriate for progress toward final build of a battery meeting the technical requirements.

Reviewer 2

The reviewer remarked that the resources appear well matched with the project's results so far.

Reviewer 3

The reviewer observed that they have many collaborations with world leaders in different areas including binder, conductive additive, and electrolytes. The reviewer added that they have support from national labs like PNNL. The reviewer concluded that the resources are very sufficient.

Reviewer 4

The reviewer stated that the funding is sufficient.

Reviewer 5

The reviewer made no comments.

Presentation Number: bat530
Presentation Title: Ultra-Low Volume Change Silicon-Dominant Nanocomposite Anodes for Long Calendar Life and Cycle Life
Principal Investigator: John Tannaci, Silanano

Presenter

John Tannaci, Silanano

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

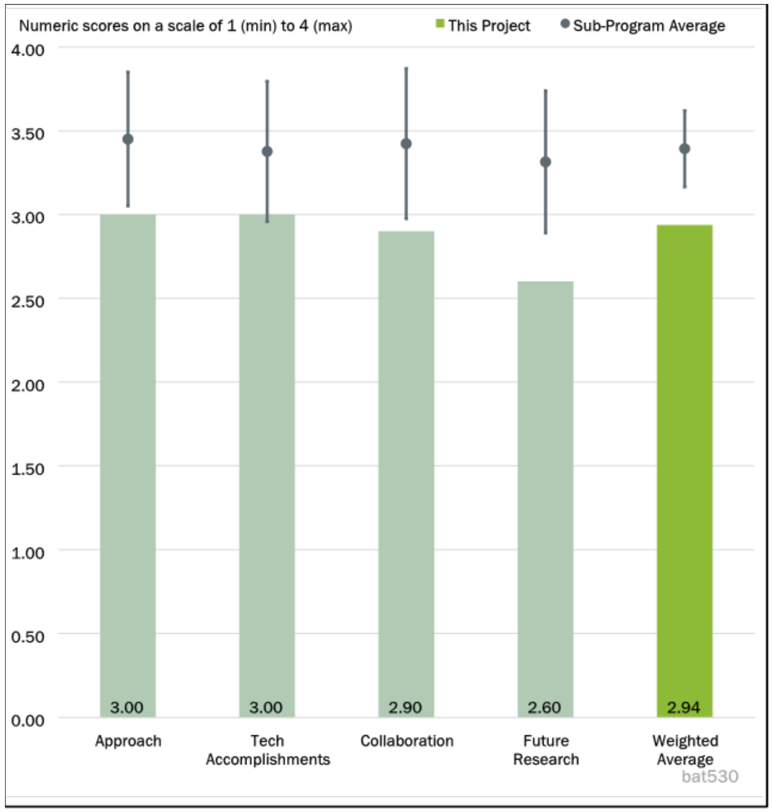

Figure 2-24 - Presentation Number: bat530 Presentation Title: Ultra-Low Volume Change Silicon-Dominant Nanocomposite Anodes for Long Calendar Life and Cycle Life Principal Investigator: John Tannaci, Silanano

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer claimed that by investigating the process-structure-property relationship and designing electrolyte, the energy density and cycling performance target will be achieved in the small format cells in the first year, and then applied to large size 1 Ah cells in the second year. The reviewer added that in the third year, the performance will be further improved to achieve high cycling performance and calendar life. The reviewer concluded that the project is well designed and has a reasonable timeline.

Reviewer 2

The reviewer expressed that Sila developed the carbon scaffold, with designed porosity, and nano-Si to mitigate the swelling issue of Si anode.

Reviewer 3

The reviewer explained that Sila's technology is promising based on initial results. The reviewer stated that the optimization of the structure has provided improved performance, but that it is difficult to determine the appropriateness of the work plan given the vague descriptions of the technology itself. The reviewer asked what the structure is, what the basics of the chemistry are, what the likely degradation mechanisms will be, what the amount of anode utilized is, and what mechanism will be used to avoid volume change during cycling.

Reviewer 4

The reviewer noted that too little technical information was provided and it is not clear how various issues were addressed.

Reviewer 5

It was not clear to the reviewer how Sila particles reduce volume changes in silicon dominated anodes. The reviewer asked if the chart on Slide 6 is supposed to be a comparison of a lithiated Sila anode and an unlithiated anode to show 250-300% increase in volume or if it just shows that Sila particles have more surface area. The reviewer expressed that Sila particles show good improvements in anode capacity as well as improved cycle life, but more tests need to be performed. The reviewer couldn't tell if only two cells were tested. The reviewer added that it was unclear what kind of cells these are and which cathodes were being used. The reviewer thought more explanation was needed on the methodologies, materials use, and testing processes. The reviewer understood that this is industry work, that not everything can be openly said, but there can still be more background on what experiments took place and how they were performed, on how many samples were considered, and so forth.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer articulated that Sila demonstrated high energy density over250 Wh/Kg, more than 750 Wh/L and over 750 cycles with 80% capacity retention by small format cells. The reviewer added that in the meantime, the calendar life is as long as over 2.5 years at 25°C in 0.2 Ah+ cells. The reviewer noted that 1Ah cells are still on track, but they already made good progress on the target.

Reviewer 2

The reviewer mentioned that the technical progress is on schedule according to the technical plan. The reviewer remarked that Phase I targets are being met, but that impedance growth should be added as a target and reported. The reviewer posed the following questions:

- Do you understand the degradation mechanism?
- What is the coulombic efficiency to the first cycle and during cycling?
- Energy density is significantly lower than the ultimate target. What is limiting it? How will this limit be overcome? Are the new particles with higher volumetric energy density enough? Is the performance and life of the enhanced particles impacted?

Reviewer 3

The reviewer claimed that some promising cycle life was demonstrated, but no details were provided in terms of cell format, electrode loading, etc.

Reviewer 4

The reviewer remarked that it seems like the project is making good progress towards its goals. The reviewer added that the work with PNNL and Army Research Lab (ARL) should produce interesting results. The reviewer expressed that the PI needs to explain with more clarity and precise language in which area the technical progress has been made and how it has been made.

Reviewer 5

The reviewer observed that they demonstrated over 1000 cycles in an LCO/Si cell with medium loading of 3 mAh/cm^2. The reviewer added that they also demonstrated 4 months of 45°C storage with higher loading of 4mAh/cm^2 but in a different cell using NMC/Si chemistry. The reviewer suggested that the team needs to report thickness change after cycling or high temperature storage.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer stated that the groups are working well together and effectively contributing as a single team.

Reviewer 2

The reviewer noted that Sila collaborated with PNNL and ARL.

Reviewer 3

The reviewer declared that a number of OEMs are working to improve anode capacity using silicon, and Sila has said they will be working with OEM partners to make automotive cells using automotive grade active cathode, which is good progress. The reviewer recommended that they should also sort out the industry level tests that are necessary to reach automotive specifications for batteries.

Reviewer 4

The reviewer expressed that Sila collaborated with PNNL to develop the electrolyte and collaborated with ARL to model and screen the electrolyte and to investigate the SEI formation mechanism. The reviewer added that the results of the modeling part was not provided in this review. The reviewer recommended that more collaboration on the electrolyte designation may be helpful for them to achieve a better cycling performance and calendar life.

Reviewer 5

The reviewer claimed that it is not quite clear what the collaborators have contributed to the program.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer mentioned that while initial results are encouraging, there are no concrete details provided to improve to Phase II targets. The reviewer suggested that more specific plans and actions should be reported to ensure confidence in the program.

Reviewer 2

The reviewer claimed that the barriers were obvious but was not sure of the developer's approach to close the gap.

Reviewer 3

The reviewer stated that there is not enough information on future work and that it is unclear what they will do to determine if they will achieve their future target. The reviewer added that the proposed work includes surface chemistry, slurry optimization, and coating density, but this is run of the mill work for any materials processing. The reviewer questioned what was getting done and asked how the team will actually achieve the future target.

Reviewer 4

The reviewer expressed that Sila will further improve their anode by surface chemistry, slurry optimization and coating density. The reviewer added that in the meantime, Sila will work with PNNL and ARL to further design the electrolyte and SEI for better performance. The reviewer noted that it might not be easy to improve their cell from over 250 Wh/Kg to 350 Wh/Kg, but that it was still possible for them to achieve it after more than one year.

Reviewer 5

The reviewer commented that in addition to demonstrating over 1000 cycles, they should report RT calendar life data projected based on their 45^{o}C data, if necessary, in cells with over 350 Wh/kg at over 4.3V charge cut-off. The reviewer stated that they also need to report thickness change at 1000 cycles and at the completion of calendar life in cells with over 350 Wh/kg in the same cells.

*Question 5: **Relevance: Does the project support the overall VTO subprogram objectives?***

Reviewer 1

The reviewer noted that the advanced Si composites are well aligned with DOE's targets for EV improvements.

Reviewer 2

The reviewer made no comments.

Reviewer 3

The reviewer stated that the increase in silicon content will increase capacity, but it has to be demonstrable on a large-scale format battery that it will have the cycle life as graphite anodes.

Reviewer 4

The reviewer claimed that Sila designed silicon-dominant nanocomposite materials which will help the development of next-generation Li-ion batteries, and that it will definitely support the batteries objectives.

Reviewer 5

The reviewer remarked that Sila's work met VTO's program objectives.

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

Reviewer 1

The reviewer commented that Sila is good at silicon nano-composite anode and EV cell building, and they have support on electrolyte from both PNNL and ARL. The reviewer added that it will make it easier for them to achieve the milestone in a timely manner.

Reviewer 2

The reviewer remarked that funding is sufficient.

Reviewer 3

The reviewer declared that it is unclear what resources are available to Sila, and that the project team should make it clear what resources they have and require to achieve their targets.

Reviewer 4

The reviewer stated that the resources appear to match outputs and that it is difficult to judge without more details on the future work scope/efforts.

Reviewer 5

The reviewer claimed that if the program will continue, much more technical details and gap analysis need to be provided. The reviewer added that the presentation was poorly prepared and that it is not clear at all where their technology is and how big the gap is to the target.

Presentation Number: bat531
Presentation Title: Solid State Lithium-ion Batteries Using Silicon Composite Anodes
Principal Investigator: Pu Zhang, Solid Power Battery

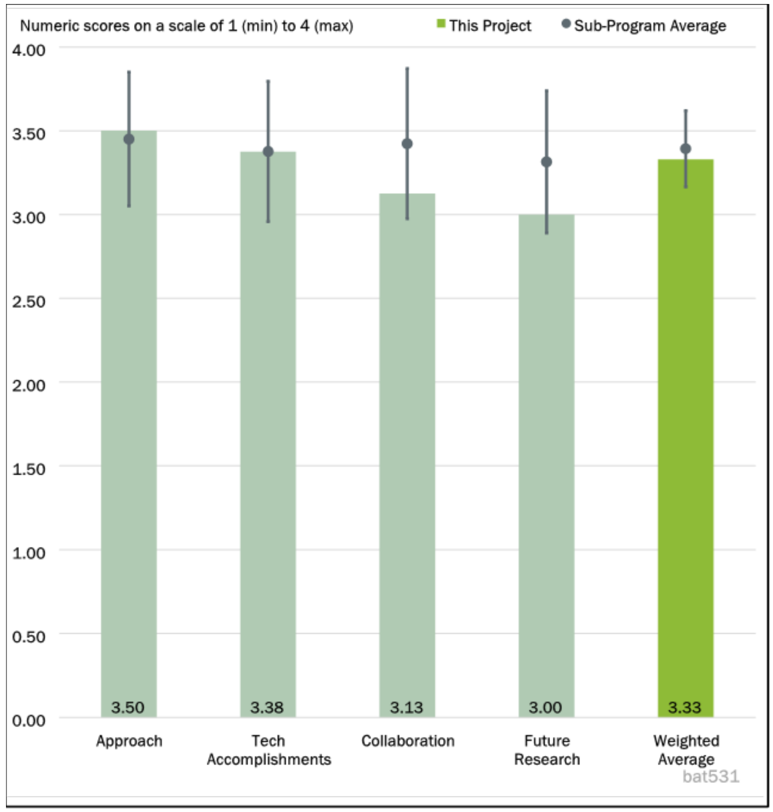

Figure 2-25 - Presentation Number: bat531 Presentation Title: Solid State Lithium-ion Batteries Using Silicon Composite Anodes Principal Investigator: Pu Zhang, Solid Power Battery

Presenter

Pu Zhang, Solid Power Battery

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer declared that the combination of the solid electrolyte and Si seems to be a good approach to address Si anode degradation in cycle and calendar life.

Reviewer 2

The reviewer remarked that the project is well designed from December 2020 to December 2022. The reviewer added that the approach of every quarter is very detailed including equipment secured, cathode selected, single cell stack, and roll-to-roll coated, which make the plan very reasonable.

Reviewer 3

The reviewer observed that Solid Power leveraged their unique solid-state electrolyte to achieve good performance in a Li-ion cell based on Si anode.

Reviewer 4

The reviewer commented that the approach relies upon sulfide material forming a stable SEI with Si composites. The reviewer claimed that this is a promising approach because sulfide materials have shown some stability to lithiated Si. The reviewer expressed that solid state, however, introduces additional issues with Si in terms of ability to handle the volume changes during lithiation. The reviewer asked if the ionic structure of the electrode survives well enough to enable long life cycling. The reviewer mentioned that understanding if this issue is critical to evaluating the approach. The reviewer observed that so far, initial cycling results look encouraging but more emphasis on degradation mechanism understanding may be necessary to meet the project's goals.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer noted that good improvement in capacity and cycle life was demonstrated. The reviewer added that the 1500 mAh/g specific capacity for Si anode delivered pretty decent cycle life performance.

Reviewer 2

The reviewer commented that Solid Power achieved Si composite anode with an electrode level capacity of 1500 mAh/g. The reviewer added that a stable cathode was developed to match the Si anode, which enabled a pouch cell with a good cycling performance of up to 500 cycles. The reviewer remarked that the target was well achieved.

Reviewer 3

The reviewer stated that the project has demonstrated that sulfide cells with Si anodes function reasonably well. The reviewer remarked that the ability to process the materials into high quality cells is impressive. The reviewer made the following comments and suggestions:

- Impedance growth needs to be measured and tracked. This is directly relevant to the stability of the ionic pathways in the anode.
- Calendar life needs to be measured and reported.
- More focus on understanding degradation mechanism will better guide future work.
- What is the structure of the Si composite? Before and after SEM images would be informative.

Reviewer 4

The reviewer claimed that they achieved over 500 cycles at 45^{o}C using NMC cells with Si dominant anode, albeit the loading was only 3mAh/cm^2, insufficient to meet the 350 Wh/kg goal.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer claimed that it is unclear what Argonne's role is. The reviewer suggested directing them toward understanding the degradation mechanism.

Reviewer 2

The reviewer made no comments.

Reviewer 3

The reviewer stated that Solid Power collaborated with ANL to do materials characterization and cell failure analysis, which will be helpful for them to learn the mechanism behind and further improve the battery performance. The reviewer suggested that it would be better to show the results from the collaboration in the review meeting.

Reviewer 4

The reviewer noted that Solid Power collaborated with ANL.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer stated that Solid Power will further improve the stability of the composite anode to achieve a better cycle life and make thinner separators to get a higher energy density. The reviewer added that considering there is still much space to further reduce the thickness of the separator, it is highly possible for them to achieve the targets.

Reviewer 2

The reviewer made no comments.

Reviewer 3

The reviewer expressed that future work should focus on loading 4 mAh/cm^2 and performance at RT or below. The reviewer added that they also need to focus on calendar life and develop an understanding on the calendar life degradation mechanism using their SSE, to validate the calendar life degradation mechanism proposed by the Si Consortium. The reviewer recommended that in addition to demonstrating over 1000 cycles, they should report RT calendar life data projected based on their 45ºC data, if necessary, in cells with over 350 Wh/kg at greater than 4.3V charge cut-off. The reviewer also suggested that they need to report thickness change at 1000 cycles and at the completion of calendar life in cells with over 350 Wh/kg in the same cells.

Reviewer 4

The reviewer observed that the proposed future research section is just a restatement of the project's goals. The reviewer explained that it does not provide any details on the flow or plan of work for the project, and that more details are needed. The reviewer added that understanding the degradation mechanism is key to effectively planning the future work to ensure successful completion of the project.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer claimed that this program combines solid state and Si anodes and that both are highly relevant to the DOE's targets.

Reviewer 2

The reviewer said yes.

Reviewer 3

The reviewer remarked that Solid Power make solid electrolyte enabling high performance Si anode, the roll-to-roll process enabling a scalable cell manufacturing, which support next-generation safe Li-ion batteries.

Reviewer 4

The reviewer observed that this effort met the VTO's program objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer claimed that additional work is needed to understand degradation mechanisms. The reviewer added that overall, however, the program might be well resourced but that resources may just need to be redirected.

Reviewer 2

The reviewer made no comments.

Reviewer 3

The reviewer stated that Solid Power have good capability to build large solid state pouch cells, and that the collaboration with ANL and DOE VTO will make the milestones achievable.

Reviewer 4

The reviewer expressed that the funding is sufficient.

Presentation Number: bat532
Presentation Title: Electrolytes with Lithium-ion Batteries with Micro-sized Silicon Anodes
Principal Investigator: Chunsheng Wang, University of Maryland

Presenter

Chunsheng Wang, University of Maryland

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

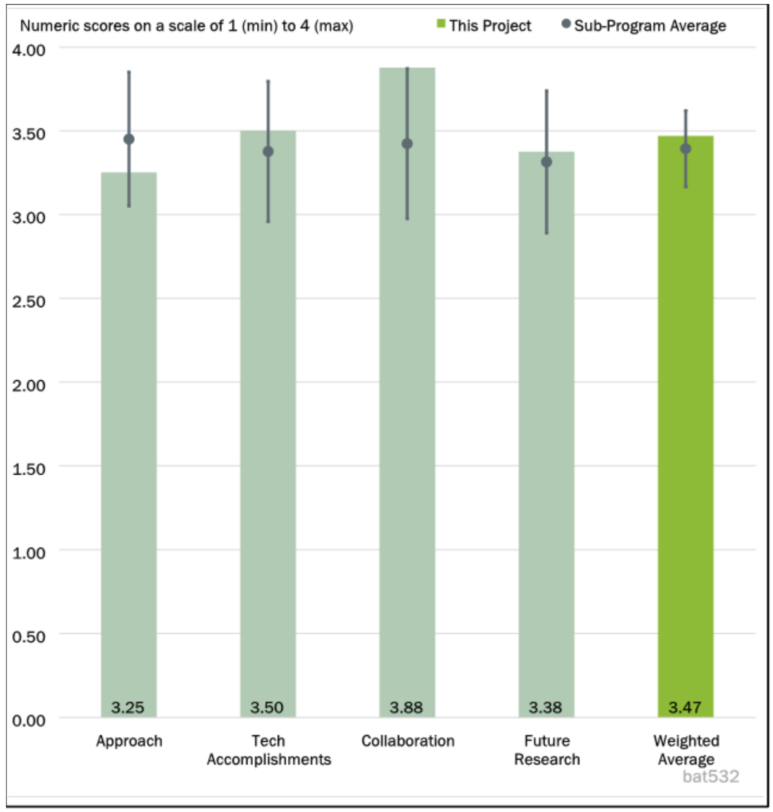

Figure 2-26 - Presentation Number: bat532 Presentation Title: Electrolytes with Lithium-ion Batteries with Micro-sized Silicon Anodes Principal Investigator: Chunsheng Wang, University of Maryland

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer mentioned that the project designs new electrolyte formulations that significantly improve the performance of silicon microparticles. The reviewer observed that uniquely, the project also breaks down the calendar life into measurable quantities, and that it is well-designed and addresses the technical barriers of silicon anode.

Reviewer 2

The reviewer suggested a quicker down selection of materials and electrolytes. The reviewer stated that a large amount of good work was completed, but more focused effort will lead to more meaningful accomplishments.

Reviewer 3

The reviewer claimed that the technical barrier for designing Electrolytes for Lithium-ion Batteries with Micro-sized Silicon Anodes is the following: finding electrolytes that will form a coherent shell around the entire micro-sized particle, while maintaining contact to the particle, not cracking, and not allowing fresh electrolyte to the particle surface. The reviewer explained that this team's approach is to try three different highly fluorinated electrolytes in an attempt to form an intact SEI film of mostly LiF around the micron-sized Si particles. The reviewer articulated that in doing so, the researcher will minimize the surface area of Si exposed to the electrolyte in all stages of formation and use. The reviewer noted that they make certain assumptions but do not actually test the assumptions. The reviewer stated that they try fluorinated electrolytes and get better results but this does not mean that their proposed mechanism is correct.

Reviewer 4

The reviewer expressed that there is a lot to unpack in this report and not a lot of details about materials and experiments. The reviewer observed that the units shown in most graphs, such as mAh/cm^2, make it difficult to estimate the gravimetric capacity or energy. The reviewer added that the basic premise is that LiF is weakly bonded to the Si, so able to form a dense, robust SEI skin that can slide to accommodate the stress from Li alloying. The reviewer claimed that assuming the liquid electrolyte does not fill the microcracks formed within the Si, the cracks can neatly close and heal when the Si is delithiated. The reviewer added that the polymer outer component of SEI is believed key to keeping the liquid out. The reviewer remarked that the approach to refining the liquid electrolytes is not evident, except that F is good. The reviewer stated that the rationale that moves the study from the THF to sulfolane to ionic liquids is not obvious, or perhaps, the approach is designed to be multiprong to quickly identify a success. The reviewer declared that while the program is set to address the Si electrode refinement as well as the electrolyte, except for comparison of cycling micro and nano Si particles, the core effort is towards the electrolyte formulation. The reviewer stated that the properties of the Si anode are not clear. The reviewer commented that while this is a new program under FOA, there has been significant earlier work that serves as the foundation, and that published work demonstrated improvements in cycle performance of 2M $LiPF_6$ in solvent mixtures such as pure THF and THF with methyl groups etc. The reviewer added that earlier work also revealed improvement from fluorinating the solvents, presumably still THF-based. The reviewer noted that almost all the results presented in the slides are electrochemical tests, with emphasis on obtaining the CE (coulombic efficiency), leakage current decay, and SEI resistance from partial fits of EIS. The reviewer added that 3D X-ray tomography and SEM are used to check for cracking in the Si anode, but otherwise reveal little about the SEI, and that there is no characterization of the SEI itself.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer claimed that through three generations of electrolyte design, the project achieved superior performance compared to existing literature.

Reviewer 2

The reviewer encouraged the addition of actual multi-temperature calendar life testing. The reviewer added that it would be helpful to summarize together, for the same material and electrolyte composition, both the cycle and calendar life.

Reviewer 3

The reviewer mentioned that technical accomplishments include showing that starting from an all fluorinate electrolyte and replacing some of the solvent with sulfolane reduced the conductivity by 20% but improves the oxidative stability to above 5.3 V. The reviewer added that in a Si/Li cell, the team achieved 99.6% CE, in an lithium-iron phosphate (LFP)/Si cell, they achieved 99.9% CE, and in an NCA/SI cell they achieved 99.3% CE. The reviewer noted that the technical accomplishments also included showing that using an ionic liquid as the electrolyte, they could remove the solvent, achieve oxidative stability to 4.5 V and decent conductivity. The reviewer remarked that a cell of Si/Li achieved a CE of 99.9% and a cell of NCM811/Si achieved a CE of

99.9 %, although the capacity of the cell in mAh/cm^2 was not provided. The reviewer claimed that the project team also demonstrated that in a high-capacity Si/Li cell (4mAh/cm^2) they could achieve good capacity retention and a CE of 99.85% when cycled at C/10, although the capacity retention declined significantly at C/5. The reviewer added that in a full cell of NMC811/Si of a capacity of 4 mAh/cm^2 the project team achieved a capacity retention of 85% after 100 cycles at C/10. The reviewer added that microscopy analysis showed no cracking of the micro-sized Si particles after 300 cycles. The reviewer commented that in half cells they performed a test protocol that included cycling and a 180-hour voltage hold, so they could measure CE from the cycling and rate of side reactions from the voltage hold. The reviewer claimed that the project team found that the cell with macro-Si and the mix THF electrolyte lost the least amount of capacity during the hold and had a similar sustained current at the end of 180 hours as graphite with a typical electrolyte. The reviewer articulated that these two cells also had the best coulombic efficiency. The reviewer noted that the cell with micro-Si also performed better than nano Si with the same electrolyte. The reviewer added that the cell with ionic liquid had the worst loss of capacity during the hold but had the lowest rate of side reactions by the end of the 180 hours. The reviewer claimed that the worst performing cell was the micro-Si with the typical electrolyte for graphite cells. The reviewer added that the EIS of the Si half cells shows that the impedance rise with the mix THF electrolyte is less than the impedance rise of the typical graphite electrolyte. The reviewer stated that overall, the PI started out with the hypothesis that larger Si would cycle better if he could encapsulate the particles with a LiF based SEI. The reviewer noted that the project team then tested the larger Si in different electrolytes with higher fluorine content and showed better performance than the less fluorinated electrolyte and smaller Si. The reviewer remarked that the project team also achieved decent full cell cycling. It was unclear to the reviewer as to whether the project team is forming an intact SEI around the micro particles or that the electrolyte itself is not as reactive. The reviewer added that the project team's micro particles may be working well because the team is cycling at a slow rate. The reviewer concluded that the project team improved the performance of the Si electrode and full cell performance, which matters.

Reviewer 4

The reviewer stated that in the current program, accomplishment number 1, sulfolane was added to the fluorinated solvent (presumably THFs), which extends the voltage window above 5V. The reviewer explained that this provides for reasonable (although noisy) cycling to 4.3V of Si//NCA cell. The reviewer added that this was not emphasized, but appears promising. The reviewer added that the sulfolane-based electrolyte was called out for future research. The reviewer claimed that accomplishment number 2, is electrolyte formed with ionic liquid solvent providing good cycling of 811 versus Li anode cells, and Si versus Li half cells results as well. The reviewer stated that this provides for separating the CE of each electrode. The reviewer added that the full cell 811//Si cycled for over 100 cycles. The reviewer highlighted that after 300 cycles, there was no noticeable cracks in the micron-sized Si particles. The reviewer expressed that accomplishment number 3 addresses the calendar life with 180-hour high voltage aging. The reviewer detailed that for this, the work cycled back to the earliest electrolytes with mixed THF. The reviewer explained that the logic here confused the reviewer. The reviewer asked why the leakage current and EIS were measured and fitted, rather than simply comparing the energy and capacity of cycles before versus after the extended high voltage hold (in this case 180 hours). The reviewer rationalized that it was perhaps to identify aging over shorter time periods. The reviewer notes that the researchers observe the transient decrease in the current at the constant voltage hold, and the rise in the SEI resistance as extracted from the fits of results. The reviewer said that no attempt was made to quantify the uncertainty and the reviewer was skeptical of the accuracy implied by three or four significant figures. The reviewer that key for this analysis reveals that side-by-side, the micro-sized Si have better calendar life than do the nano-Si particles.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer observed that the roles and responsibilities are clearly defined.

Reviewer 2

The reviewer noted that the recipient works with Brookhaven National lab to characterize the Si electrode after cycling, which is important to the success of the project.

Reviewer 3

The reviewer noted that this is a team of 4 different institutions that each have a particular role to play and that there is pretty good coordination in that respect.

Reviewer 4

The reviewer remarked that vital collaborators are Kang Xu and Oleg Boridin at Army Research Lab, providing fundamental and theoretical guidance for electrolyte formulations based on long experience. The reviewer noted that Saft is important for electrode coating and engagement as an industry partner. The reviewer observed that Stony Brook University provides synchrotron study of electrodes. The reviewer suggested that perhaps additional collaborations can provide needed ex- and in-situ characterizations of the SEI formation and aging.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer stated that the project team wants to build a mathematical model that explains why large particles and F-rich SEI’s leads to better performance. The reviewer added that the project team wants to optimize the formulation of its electrolyte with sulfolane for full cells. The reviewer observed that the project team wants to find a way to reduce the viscosity of their ionic liquid electrolyte. The reviewer commented that all of this is fine, but the project team never measured the calendar life of a full system. The reviewer added that before optimizing any electrolyte or modeling a system it would be nice to know if the project team is even close to a target of ten-year calendar life.

Reviewer 2

The reviewer stated that it would be useful to invest some time to evaluate the SEI formed on the Si in order to test the basic premise of this work. The reviewer added that the basic premise is that LiF is weakly bonded to the Si, so able to form a dense, robust SEI skin that can slide to accommodate the stress from Li alloying. The reviewer claimed that assuming the liquid electrolyte does not fill the microcracks formed within the Si, the cracks can heal when the Si is delithiated. The reviewer expressed that the polymer outer component of SEI is believed key to keep the liquid out. The reviewer suggested that instead of characterizing the SEI and its growth/dissolution with spectroscopic and physical analysis, the future work proposes modeling the degradation and relies on calendar life as measured by leakage current and EIS. The reviewer noted that this approach differs from other researchers. The reviewer declared that other future work will continue investigations and improvement of both the sulfolane and ionic liquid electrolytes. The reviewer concluded that there are likely opportunities to improve both of these electrolyte systems.

Reviewer 3

The reviewer recommended adding the actual calendar life testing to provide validation to the modeling exercise.

Reviewer 4

The reviewer noted that the presenter ran out of time, so the future work was not clearly described and no questions and answers were conducted. The reviewer added that based on the achievements, it is likely that the project will continue to deliver good results.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer stated that the project supports the VTO subprogram objectives in that it seeks to improve the performance of Si in cells which, if successful, should lead to higher energy density cells.

Reviewer 2

The reviewer expressed that this project supports the overall DOE objectives by extending the calendar life of silicon anode.

Reviewer 3

The reviewer claimed that the study of advanced electrolytes for high voltage cells utilizing Si anode is highly relevant for success of the VTO program. The reviewer added that it would be helpful if the investigation provided results in the same units as the specs written for the program, namely Wh/kg and Si content of the anode.

Reviewer 4

The reviewer remarked that the effort does support the goals of the VTO subprogram, and that the emphasis on micro-scale Si is especially relevant. The reviewer added that it is unclear if there are other significant barriers, such as cost, to the electrolyte systems under consideration. The reviewer commented that it would be good to at least acknowledge their potential impact.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated that VTO is suggested to increase funding for productive projects like this.

Reviewer 2

The reviewer claimed that the resources are sufficient in that it is $1 million spread over 2 years. The reviewer added that the University of Maryland only has to pay for some work at ARL, and that they get free work from Saft and Brookhaven.

Reviewer 3

The reviewer stated that they are sufficient for a new university lead experimental program.

Reviewer 4

The reviewer remarked that the effort appears well resourced.

Presentation Number: bat533
Presentation Title: Fluorinated Local High Concentration Electrolytes Enabling High Energy Density Silicon Anodes
Principal Investigator: Amy Marschilok, Stony Brook University

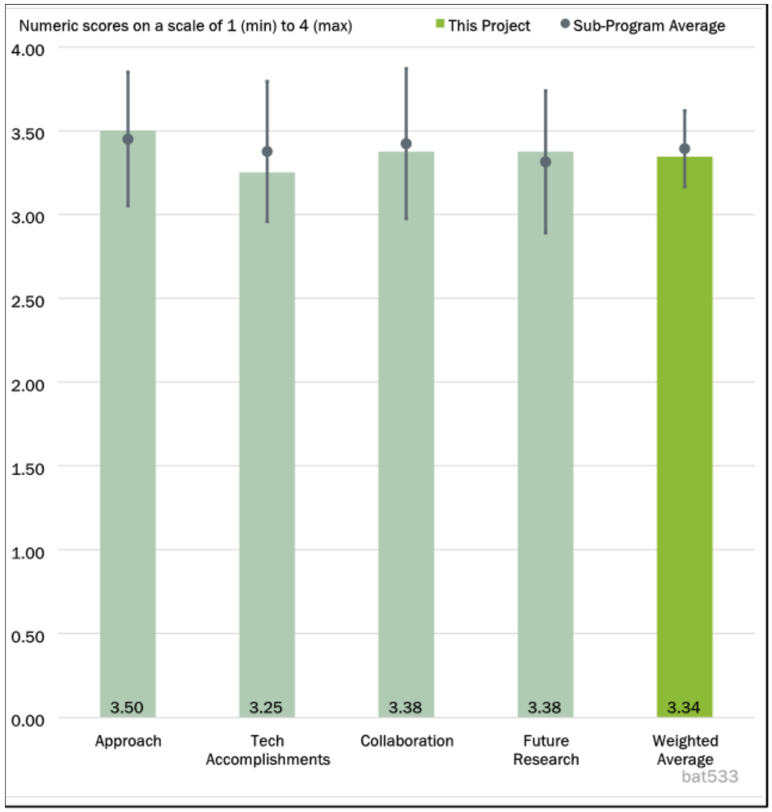

Figure 2-27 - Presentation Number: bat533 Presentation Title: Fluorinated Local High Concentration Electrolytes Enabling High Energy Density Silicon Anodes Principal Investigator: Amy Marschilok, Stony Brook University

Presenter

Amy Marschilok, Stony Brook University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer commented that the technical barrier is developing an electrolyte that will allow for 10 years of calendar life. The reviewer stated that the approach is to design an electrolyte where there is fluorine in the anion and in the solvent. The reviewer mentioned that the project team will use a fluorinated localized high concentration electrolyte in this effort, and hope this will work. The reviewer declared that there have been indications that SEI films with high fluorine content passivate surfaces better than SEI's without fluorine. The reviewer claimed that the timeline is to try two sets of electrolytes and measure their progress.

Reviewer 2

The reviewer stated that this is a complex study with many factors that influence the success of a new electrolyte. The reviewer claimed that while the program is directed towards Si anodes, full cell tests dictate that performance must enhance both the composite anode and high Ni (622) cathode. The reviewer mentioned that earlier studies by groups investigating similar LHCE used the lower voltage 532 and 333 cathodes. The reviewer added that while this study is supporting the effort to stabilize the Si anode, the cathode chosen itself presents significant challenges as it has a higher Ni content (622) than earlier studies with LHCE local high concentrated electrolyte contain non-solvating diluent. The reviewer remarked that the initial approach used a control of $LiPF_6$ EC/ dimethyl carbonate (DMC), but this is well known to be ineffective in Si cells. The reviewer observed that the capacity loss is following a very different rate dependence for this control. The reviewer stated that the research team wisely switched to comparison of their novel electrolytes to the 1M electrolytes with FEC addition. The reviewer concluded that this is a better "control" or reference for the current fluorinated localized high-concentration electrolyte (FLHCE) study because the work is more likely to reveal the effects of diluent and fluoridated cosolvents.

Reviewer 3

The reviewer remarked that the approach is well thought out and systematic

Reviewer 4

The reviewer commented that the project evaluated several electrolyte solvent molecules to address the technical barriers of Si anode, and that it will be more effective when directed by rational design.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer expressed that at this meeting the project team presented progress on their first-generation electrolyte, which consists of four variations of LiFSI, FEC, FEMC, and TTE (all materials are fluorinated). The reviewer added that when compared to EC:EMC, they all have higher viscosity and lower conductivity. The reviewer mentioned that amongst themselves, the order in conductivity and viscosity is the same order as the concentration of LiFSI - high LFSI correlates to high conductivity and viscosity. The reviewer claimed that the contact angle of these electrolytes shows better wetting on the separator than the typical Li-ion electrolyte shows. The reviewer explained that these FLCHEs show least voltage stability but are good enough for most Li-ion cathodes and the LiFSI does not show aluminum corrosion as it does in EC:EMC. The reviewer remarked that the capacity fade of the full cells made with the FLHCE all show about the same rate. The reviewer claimed that there are differences in initial capacity that can be attributed to differences in impedance. The reviewer observed that with regard to impedance, the control electrolyte starts with less impedance than the FLHCEs, but this rapidly changes with cycling with the control growing much worse. The reviewer stated that the PI also introduced the second-generation electrolyte. The reviewer clarified that this contains similar solvents as the first generation but with the replacement of TTE with BTFE and TFEPE. The reviewer added that the next set of electrolytes have a wider range of viscosity than the first generation (in general, slightly higher), and about the same contact angle as the control (less wetting than the first generation). The reviewer concluded that in general, the first-generation electrolytes (FLHCEs) were better than the control (EC:EMC), and that there is no clear indication that the second generation will be better that the first.

Reviewer 2

The reviewer remarked that it is still early as this is a new Si anode FOA program. The reviewer noted that significant progress was demonstrated in exploring new liquid electrolytes. The reviewer added that while following the lead from other research teams, notably Wu and Zhang at PNNL, these compositions are new and Gen 1 compositions already demonstrate a slight performance exceeding that of standard electrolytes with the FEC additive. The reviewer remarked that much is being studied and reported about the electrolytes, including viscosity, conductivity, and separator wetting, as well as the electrochemical stability and performance in full Si/NMC cell and various reference cells with graphite and LFP electrodes. The reviewer expressed that it is exciting to see isothermal microcalorimetry used for this study. The reviewer stated that a wise comparison was made at the 15th cycle control, so that remaining capacity is comparable. The reviewer wondered if comparing X-ray photoelectron spectroscopy and EIS for comparable capacity, 80%, would be formative than at a specific cycle number particularly for controls near zero capacity. The reviewer had questions for the PI, but time ran out. The reviewer asked the following: How much liquid was used in each cell? Can volume of mixing when diluent be used to learn about ion association and solvation? Why not start with maximum 4M salt solution? The reviewer added that the table on Slide 6 of Gen 1 electrolytes indicates that salt concentration is significantly higher for number four than for number two, yet text suggests that the two are comparable and number two is highlighted.

Reviewer 3

The reviewer said that the work completed so far is systematic and consistent, and looks forward to data from year 2 and 3 goals which will tie together answers to the key questions.

Reviewer 4

The reviewer claimed that performance improvement is shown, but the absolute performance is still not as good as the best literature values. The reviewer explained that for example, the percentage of Si is only 30% (the minimum of DOE target), and cycle life is only 100 cycles (much lower than DOE target).

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer stated that there is a strong collaboration with BNL but nothing more. The reviewer added that the project team should find a way to work with the Si consortium and share electrodes and electrolytes.

Reviewer 2

The reviewer noted that collaborations are limited to BNL and Stony Brook University, which is sufficient at this stage in new FOA. The reviewer added that the source of cell test electrodes is not clear. The reviewer explained that if made at Stony Brook University, it may be useful to coordinate with CAMP or industrial electrode fabrication. The reviewer stated that collaborations to view the SEI and CEI evolution with voltage and cycle age may be achieved most efficiently with aid of another program.

Reviewer 3

The reviewer noted that it was very clear who is doing what and what partner skills and resources are being brought to the table.

Reviewer 4

The reviewer stated that the recipient works with Brookhaven National Lab. The reviewer added that the project would be more productive if one other university collaborator with extensive and complementary expertise on Si anode is involved.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer remarked that the future work involves characterizing the Gen 2 electrolyte to the same extent the Gen 1 was. The reviewer stated that the project team also wants to perform more isocalorimetry and that their goal is to demonstrate 20% capacity improvement over EC:EMC at cycle 100, but the EC:EMC only maintains 10% of its original capacity at 100 cycles, so this is not a great accomplishment. The reviewer declared that there is no guarantee that Gen 2 will be any better than Gen 1. The reviewer observed that the project team also expects to demonstrate a 50% capacity retention improvement at 500 cycles, which is essentially a 50% capacity retention in total. The reviewer recommended that there needs to be more of an analysis between Gen 1 and Gen 2 and what else is going on with Si to move to a better electrolyte. The reviewer said that it is possible that a particular formulation will hit a home run, but it is not apparent in any of the presentations at this AMR.

Reviewer 2

The reviewer declared that yes indeed, future research is well defined and likely to be successful. The reviewer added that it is important to reveal scientific understanding as well as achieving capacity retention. The reviewer noted that future work will emphasize alternative diluents, both different molecules and different concentrations, and that this is the most important and interesting part of study. The reviewer added that the PI plans to assess CEI formation and variation with each deep cycle. The reviewer observed that the premise is that the thin inorganic SEI at the Si interface (LiF + Li oxide is more stable than a composite SEI with organics. The reviewer explained that whether it is expected to rapidly grow and shrink with Si cycling, or rapidly passivate any microcrack formation, or both, is not clear from the presentation. The reviewer suggested that the observation of the SEI (and CEI) variation during a full cycle, or at least at full charge and full discharge states, would be enlightening, but also potentially rather complicated study for Si + C composite. The reviewer stated that to achieve best practical cycling performance, additional effort will be productive following the PI's intuition to with salt compositions and additives. The reviewer added that study of calendar life will be initiated in future work and that it will use the prescribed method of applying an extended hold at high V and noting small leakage current. The reviewer concluded that while this is a simple means to isolate side reactions that occur at higher V, demonstrating its relevance for the Si SEI formation may be ambiguous and the PI may have freedom to adjust such a test.

Reviewer 3

The reviewer encouraged calendar life tests to include actual, multi-temperature calendar life tests, in addition to voltage hold tests.

Reviewer 4

The reviewer commented that the goal of improving the performance was described, and that it would be more convincing if hypothesis is clearly laid out.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said that this work supports the overall VTO subprogram objectives to increase energy density by finding ways to get experimental electrode materials to perform better.

Reviewer 2

The reviewer stated that this program is highly relevant to achieving required cycle life, calendar life, voltage stability needed to achieve the higher energy density of Si anodes as substitution for graphite anode in Li-ion batteries. The reviewer added that the best electrolyte formulation considering cost, safety in addition to cycling performance warrants additional study under investigation in this program.

Reviewer 3

The reviewer expressed that this is highly relevant to the study and advancement of Si anodes; however, some acknowledgment of other barriers, such as cost, environmental impact, etc. would be helpful.

Reviewer 4

The reviewer claimed that this project supports the overall DOE objectives by extending the calendar life of silicon anode.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated that the resources are sufficient to support the work proposed.

Reviewer 2

The reviewer expressed that they are sufficient for new university led experimental programs.

Reviewer 3

The reviewer claimed that effort appears well resourced and funded.

Reviewer 4

The reviewer said that some aspects of the project (e.g., combining electrolyte with engineered silicon anode materials) would benefit from working with another university.

Presentation Number: bat534
Presentation Title: Devising mechanically compliant and chemically stable synthetic solid-electrolyte interphases on silicon
Principal Investigator: Pierre Yao, University of Delaware

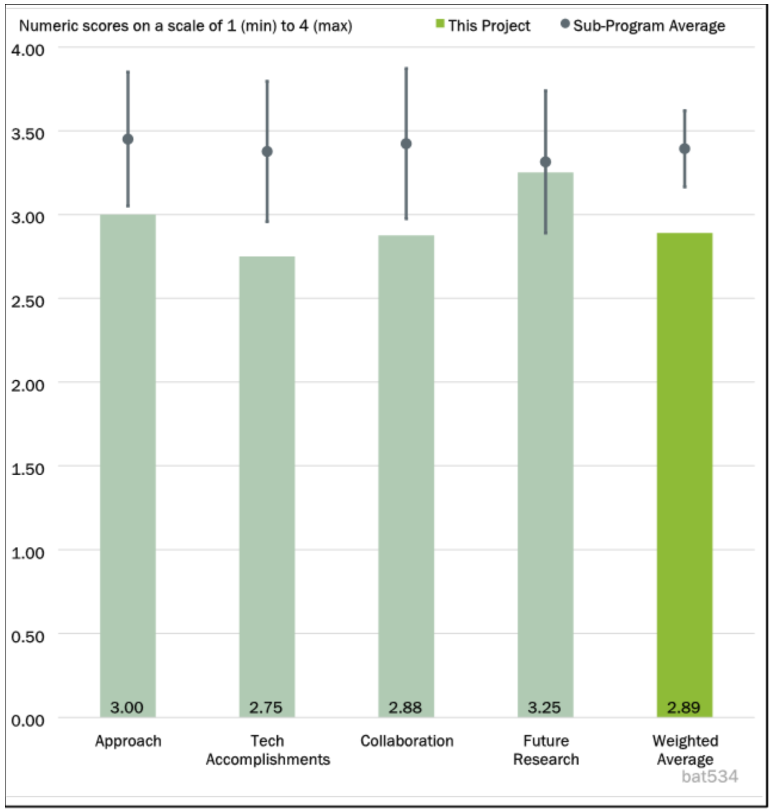

Figure 2-28 - Presentation Number: bat534 Presentation Title: Devising mechanically compliant and chemically stable synthetic solid-electrolyte interphases on silicon Principal Investigator: Pierre Yao, University of Delaware

Presenter

Pierre Yao, University of Delaware

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer stated that the investigators want to apply a polymeric/elastomeric artificial SEI on the surface of Si to passivate the surface, and that they want to apply it either through electropolymerization or electrodeposition. The reviewer added that they are going to test a number of polymers for solvent stability and surface conformity, and expect to identify at least one conformal coating by the time of this review. The reviewer claimed that they then expect to produce a number of protected Si electrodes and test them in full cells against an NMC cathode. The reviewer concluded that their plan is straight forward and reasonable.

Reviewer 2

The reviewer observed that the approach is simple and attractive: Synthesize and coat Si anode ex-situ to allow for greater choice and control of the artificial SEI than can be achieved in the actual battery. The reviewer noted that with an electrodeposition solution coating process, there is an opportunity to conformally coat even porous Si electrodes. The reviewer added that early results for this new program showed promise but are very preliminary. The reviewer stated that the approach used both: electropolymerization EP, where monomers are polymerized on surface; and electrophoretic deposition (EPD), from solutions already containing polymers of interest. The reviewer observed that as these methods are not self-limiting, the synthetic SEI thickness can be adjusted with the deposition time. The reviewer articulated that Si electrode samples were fabricated as thin film, 40 nm thick, on copper foil which provided a convenient electrode for the synthetic SEI deposition and allowed for good characterization of the surface coating by FTIR and AFM methods. The reviewer said that subsequently the SEI-coated Si film was tested in coin cell versus Li with standard LiPF6-EC+DMC electrolyte. The reviewer suggested that perhaps a better electrolyte would include the FEC additive. The reviewer added that it appeared that there was some contamination or other non-uniformity of the Si thin film that influenced the conformity of the polymer coatings. The reviewer remarked that cast particle electrodes (presumably from CAMP) with nanoparticles of Si with carbon and polyvinylidene difluoride (PVDF) binder (PAA was not stable in the EPD solution) were also used for Si anodes for coating and cycling. The reviewer concluded that after coating and cycling, the composite electrode delaminated from the metal foil, so this was not a good test of the chitosan SEI.

Reviewer 3

The reviewer liked the approach of separating the SEI formation outside the formation of the anode itself.

Reviewer 4

The reviewer expressed that the idea of artificial SEI has been extensively tested in literature, and that the approach in this project is not an advance to what has been tested, and the hypothesis is not well-described.

*Question 2: **Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.***

Reviewer 1

The reviewer expressed that to evaluate an electropolymerization approach, the project team produced a model surface through deposition of a thin film of Si onto copper foil. The reviewer added that the project team decided to try THF as the monomer as Li-TFSI salt dissolves in THF. The reviewer explained that they developed a beaker cell for depositing polymers onto the SI film and a number of instruments to characterize the film once deposited, including ATR-FTIR spectroscopy, AFM nano IR spectroscopy, and Thermo-Fischer. The reviewer explained that they tried electropolymerization of styrene to polystyrene and found that it was not uniformly deposited on the Si film. The reviewer mentioned that they tried electropolymerization of polythiophene and found it uniformly deposited onto stainless steel but not silicon. The reviewer described that they tried electrophoretic deposition of chitosan and found that they could uniformly deposit it on a film of Si. The reviewer claimed that they showed they could get more lithium into a Si thin film when chitosan was deposited on its surface, and that the impedance rise of the Si surface was less after cycling when coated with chitosan. The reviewer added that they then moved to a composite Si electrode with 70% Si (Paraclete), 15% carbon additive and 15% binder and found improved cycling as the amount of electrophoretic deposition of chitosan increased. The reviewer concluded that these accomplishments indicate steady progress.

Reviewer 2

The reviewer noted that using homemade Si film, there were problems achieving a conformal coating of either polystyrene or polythiophene, and that better EP films were achieved on stainless steel substrates. The reviewer added that characterizations of the Si film properties, such as crystallinity and surface contamination, were not presented, and that likely the Si is amorphous. The reviewer observed that the best coating to date was EPD of chitosan, about 2um thick after 1 minute at 2V EPD onto the 40nm Si film coated copper. The reviewer said that this chitosan SEI coating did not block the Li cycling of the Si any more than for the natural SEI formed at the bare Si film, and that both were highly resistive. The reviewer detailed that the observation that the chitosan coating approximately tripled the first cycle capacity loss compared to the uncoated Si anode is concerning as prelithiation will likely be needed and should be investigated at an early opportunity. The reviewer mentioned that chitosan coating was also achieved on nano-silicon 70% composite electrodes, and that this chitosan coated Si particle electrode showed rapid capacity degradation after only 4 cycles in Li half-cell assembled in coin cell. The reviewer added that thicker chitosan coatings did not improve this as much as one might expect, and the whole anode coating spalled from the foil current collector. The reviewer commented that alternative fabrication is needed for the Si particulate anode or alternatively, porous Si anodes are called for and noted in the future research directions. The reviewer stated that the first go/no-go milestone was to demonstrate 50% strain and that it would be good to see this result and the testing method. The reviewer claimed that this is an important advantage of the elastomer coating over the inorganic SEI formation, and that the elastomer properties should be measured before and after any prelithiation process.

Reviewer 3

The reviewer suggested that a radically different approach like this clearly has more barriers to overcome. The reviewer posed a few key questions:

- Requiring a PVDF binder is a major issue that is incompatible with the thrust of research and commercial application.
- It is not clear what the deposition uniformity is on a porous electrode.
- Does the chitosan material have the necessary mechanical properties to withstand repeated expansion and contraction?

Reviewer 4

The reviewer noted that the initial idea was not successful and that the performance is far from the target. The reviewer questioned the timely completion of the project.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said that their source for electrodes is Argonne, and that they also consult with Argonne about Si in general.

Reviewer 2

The reviewer declared that collaboration with CAMP and ANL for electrodes and guidance on cell fabrication is useful, but given the different conditions required to form the SEI by EPD and EP, the anodes require significant modification, such as for the binder and porosity. The reviewer mentioned that other project teams may be able to provide alternative or more suitable anodes.

Reviewer 3

The reviewer noted that this is a multi-disciplinary effort that may be aided by collaboration from other entities. The reviewer asked if there is sufficient knowledge and skill within the team to develop an electrophoretic deposition process, or if there is opportunity to enhance collaboration and accomplishments by bringing in talent from other areas where electrophoretic deposition is routine done, such as paints and corrosion coatings.

Reviewer 4

The reviewer noted that the collaboration with Argonne National Lab seems to be ineffective. The reviewer explained that the team had a hard time to reach the baseline performance and appears to lack technical expertise on Si anode.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer commented that in the future they will try their process on electrodes from Argonne based on P84 binder, which has shown some success in the Si Consortium Project. The reviewer mentioned that they hope to pretest in coin cells and that depending on the results, they intend to test other coatings applied by electrophoretic deposition. The reviewer concluded that it is a straight forward and clear plan.

Reviewer 2

The reviewer suggested that future research will continue on the same pathway, as a number of issues need to be resolved to determine if this approach can offer success to form a stabilized Si anode with a synthetic SEI coating. The reviewer was not overly optimistic that this will prove successful, as most research activities have determined that the inorganic SEI coatings provide better protection to stabilize the Si anode. The reviewer noted that elastomeric coating make sense if they passivate the surface and do not grow to a thick and resistive SEI.

Reviewer 3

The reviewer encouraged incorporation of some of the above comments, and added that it would be good to obtain impact of chitosan material and thickness on first cycle efficiency of the system.

Reviewer 4

The reviewer declared that some of the future plans are good (e.g., replacing PVDF with advanced binder), but there is still concern on the capability of the team to achieve comparable baseline performance as in the community.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer stated that the program is very relevant to VTO objectives as it seeks new SEI films for Si, and that this will be needed to get Si to work as an anode in Li-ion cells.

Reviewer 2

The reviewer declared that while a long way from coming close to the goals of the Si battery program, this program offers an alternative approach to depositing the SEI coating. The reviewer noted that others have similarly tried to prepare electrodes (Li, graphite, Si) with ex-situ or 'synthetic' SEI coatings materials and methods, but had limited success. The reviewer said that it is a challenging undertaking; nevertheless, this approach is definitely worth revisiting.

Reviewer 3

The reviewer observed that this type of radically different approach to solving difficult problems is highly appreciated and encouraged.

Reviewer 4

The reviewer noted that while having a lot of difficulties in execution, the goal of this project supports the overall DOE objectives by extending the calendar life of silicon anode.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said that the PI appears to be making good progress with the present resources.

Reviewer 2

The reviewer noted that resources were sufficient for new university led experimental program.

Reviewer 3

The reviewer asked to please see comment for question 6.

Reviewer 4

The reviewer commented that the team would benefit from having another university partner, to tap into expertise on Si anode without using too much budget.

Presentation Number: bat553
Presentation Title: Understanding solid electrolyte interphase (SEI) reactions in Lithium metal and Lithium-Sulfur batteries
Principal Investigator: Perla Balbuena, Texas A&M University

Presenter

Perla Balbuena, Texas A&M University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

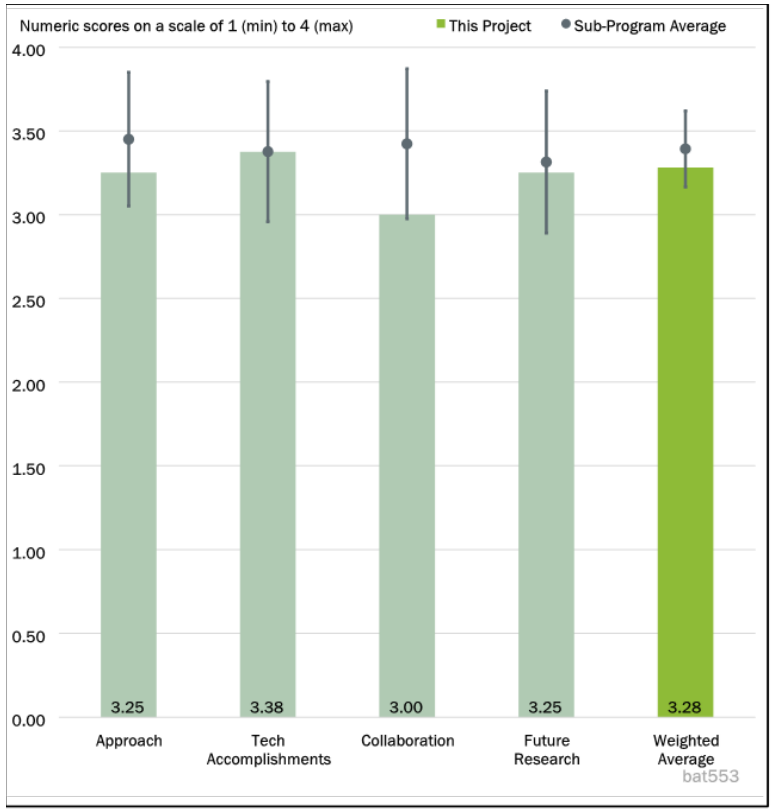

Figure 2-29 - Presentation Number: bat553 Presentation Title: Understanding solid electrolyte interphase (SEI) reactions in Lithium metal and Lithium-Sulfur batteries Principal Investigator: Perla Balbuena, Texas A&M University

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer stated that this work is oriented towards fundamental understanding of the chemistry, charge transfer, and other processes at the SEI layer. The reviewer claimed that such fundamental understanding may be important for achieving the ultimate Battery500 goals, and is generally helpful to help understand limitations on system performance, why a system degrades, etc. The reviewer added that one area for improvement in the approach would be to have specific experimental observations to be explained and orient at least some of the modeling work around capturing those observations. The reviewer explained that this could be a charge transfer resistance, a capacitance, a composition or SEI thickness, etc. The reviewer concluded that the work does a nice job of presenting quantitative results, but the connection to experiment is not as clear.

Reviewer 2

The reviewer noted that MD simulation is an important part of the battery research project, especially, if its results can be verified by experiment and used to guide cell developments.

Reviewer 3

The reviewer claimed that the approach to the work is appropriate and the research for the planned milestones is well designed. The researcher articulated that to understand the reactions near and in the solid electrolyte interface (SEI), the researchers have carried out ab initio molecular dynamics and theoretical modeling to identify and characterize the key reaction steps at the atomic level. The reviewer added that they are also conducting simulations to unravel relevant effects in the SEI region, including the salt concentration, solvent chemistry, SEI morphology, ion transport and external pressure. The reviewer claimed that in the technical aspect, they have adopted the "Blue Moon" ensemble to correct the calculated free energy from the constrained molecular dynamics simulations. The reviewer stated that the results from these studies can help to understand and possibly guide experiments.

Reviewer 4

The reviewer observed that the project is well designed and has been reasonably planned.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer observed that there are a significant number of new results, and with a good level of detail, and in different areas, including for example the work on pressure effects on reactions. The reviewer claimed that this group is working with the materials from the Battery500 consortium, and is being productive in looking at key issues associated with SEI processes.

Reviewer 2

The reviewer stated that the team has conducted extensive simulation works on interfacial resistance, SEI morphology, ion transportation, and external pressure effects. The reviewer didn't see any attempts to compare the results to experiments or to explain existing experimental results.

Reviewer 3

The reviewer noted that the current progress is fit, and that the researchers have completed the milestone of Q1. The reviewer added that the key steps and the barriers at the interface region have been identified and characterized using constrained ab initio molecular dynamics simulations and density functional theory calculations. The reviewer declared that they have also made substantial progress to reach the planned targets for Q2-Q4.

Reviewer 4

The reviewer declared that the work done is an early phase of the project, and that the PI should emphasize more on what are products of SEI. The reviewer stated that the pressure effect on reactions at porous interphasial structures characterized are not clear and asked how the ionic conductivity across the interface is.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said that it is clear this team is modeling materials of interest to Battery500, but it is hard to tell if there are significant direct collaborations with other modeling groups in Battery500, or experimental groups.

The reviewer recommended that some more direct touch points with experimental groups could help focus this work.

Reviewer 2

The reviewer stated that the team has listed collaborations with experimental teams from universities and national labs, and hopes to see works combining the simulation with the experiment reported in their next annual review.

Reviewer 3

The reviewer observed that in the current progress report, the comparison between the theoretical results and the experimental ones is lacking. The reviewer explained that since more experimentally related factors are under study, the researchers could show more modeling-experiment combined results in the future.

Reviewer 4

The reviewer made no comment on this.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said that the proposed future research would benefit from using at least a couple of SMART milestones. The reviewer noted that, as written, there are goals such as “study”, “investigate”, “characterize” but no specific and quantitative goals that could help a reviewer assess the progress in the work.

Reviewer 2

The reviewer commented that the proposed c-AIMD works are interesting and are concentrated in SEI structures. The reviewer recommended that the simulation work be combined with the experiment, or even better, to provide clues to guide better cell design.

Reviewer 3

The reviewer stated that the project has clearly identified the undergoing and the future work, and that the currently planned research steps are reasonable and can serve well for the targets.

Reviewer 4

The reviewer noted that the project has clearly defined a purpose for future work.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer stated that the work is relevant to Battery500, which is clearly relevant to the VTO goals.

Reviewer 2

The reviewer said the simulation is an important part of the battery research project and can contribute in general to the VTO objectives.

Reviewer 3

The reviewer commented that the studies can support the VTO subprogram objectives in the areas including Batteries and Analysis.

Reviewer 4

The reviewer noted that the project does support the VTO Battery500 program.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said that Battery500 resources are appropriate for such a large effort with different types of work (from fundamental to cell building).

Reviewer 2

The reviewer stated that the team has sufficient resource for their project.

Reviewer 3

The reviewer noted that according to the current progress made, the resources are sufficient for the project. The reviewer added that the researchers are simulating large systems and they are planning to use classical force fields generated by ab initio density functional calculations to complete the tasks. The reviewer said that these calculations are affordable with the current computing resources.

Reviewer 4

The reviewer commented that the resources of the project are sufficient to achieve the project milestones.

Presentation Number: bat554
Presentation Title: Fabricate and Test Solid-State Ceramic Electrolytes and Electrolyte/Cathode Laminates
Principal Investigator: Mike Tucker, Lawrence Berkeley National Laboratory

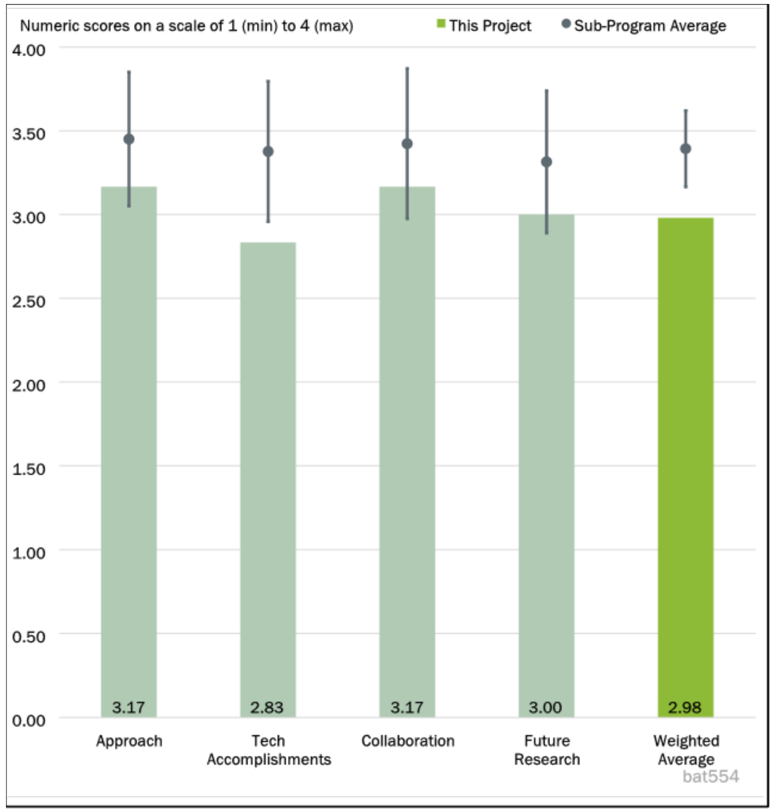

Figure 2-30 - Presentation Number: bat554 Presentation Title: Fabricate and Test Solid-State Ceramic Electrolytes and Electrolyte/Cathode Laminates Principal Investigator: Mike Tucker, Lawrence Berkeley National Laboratory

Presenter

Mike Tucker, LBNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer stated that this is an interesting approach, similar to what Eric Wachsman at the University of Maryland has worked on. The reviewer added that the goal of making a thin electrolyte and thick cathode is important and clearly a focus in the work, and that the approach leverages the experience of the PI with ceramics processing.

Reviewer 2

The reviewer remarked that the focus of this project is to develop scalable methods to form thin sheets of lithium lanthanum zirconium oxide (LLZO), interfaced with a porous scaffold that will be infiltrated with cathode active material. The reviewer added that the advantage of this approach, compared to pre-mixing cathode particles with LLZO before sintering, is that the sintering temperatures required are too high, and result in reactivity with the cathodes. The reviewer claimed that a disadvantage/challenge of this approach is the difficulty in achieving infiltration of the porous scaffold, which has not yet been achieved. The reviewer said that other novel aspect of this work is the incorporation of MgO particles to control LLZO grain size, and the introduction of an organic cathode that should be easier to infiltrate. The reviewer expressed that the project is well designed with a reasonable timeline and that the remaining technical barriers that have not yet been fully addressed include demonstrating the effectiveness of the infiltration of the cathode, measuring CCD, and improving energy density and rate capability to technologically-relevant values. The reviewer mentioned another barrier that remains to be addressed is improving the fundamental understanding of why the observed capacity fade occurs, which is not fully understood.

Reviewer 3

The reviewer expressed that the overall project technical barriers were not presented. The reviewer believed the poster template format did not include the overall project timeline; however, the technical barriers are somewhat addressed. The reviewer added that the dendrite formation did not appear to be addressed. The reviewer commented that the LLZO scaffold content was studied by means engineering porosity; however, achieving high (over 70%) porosity may be challenging while maintaining adequate mechanical integrity to prevent disintegration during operation.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer stated that the goal of making and demonstrating a full cell in 3.5 years with $1M budget is a really challenging one. The reviewer added that the team appears to have made some progress, and does show some cell cycling results, but it looks like a liquid catholyte was used for some tests (which wouldn't meet VTO goals), and there are some missing details for other cell tests (e.g., the one with an all-solid-state cell, what is the loading?). The reviewer claimed that as the project is ending, it will be important for the authors to publish on the challenges they faced, and "lessons learned" from what they attempted in this project.

Reviewer 2

The reviewer noted that the progress on ceramic manufacturing, including the dense and porous microstructures is on track and successful. The reviewer remarked that a noteworthy accomplishment is the control of grain size through introduction of MgO. The reviewer added that full cell development, especially with regards to achieving high energy density and good rate capability, appears to be a bit behind schedule, but is the focus of the remaining two quarters.

Reviewer 3

The reviewer said that based on the project timeline for FY 2022, most of the objectives were satisfactorily met. The reviewer clarified that for example, the FY 2022 Q1 and Q2 plans were to fabricate LLZO scaffolds and infiltrate them with a liquid cathode, and it was achieved. The reviewer added that the Q3 and Q4 milestones were not due at the time the slides were submitted.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer stated that Collaboration with two companies is mentioned, although the significance of that work is hard to assess. The reviewer added that given the limited size of the budget for this project, having it mostly happen within LBNL is appropriate.

Reviewer 2

The reviewer noted that the team has identified multiple collaborators, including a company that is supplying sub-micron sized NMC powders that should be more compatible with infiltration into the porous structure.

Reviewer 3

The reviewer declared that the project team appears to be effectively collaborating and Ragan is providing shear compaction expertise.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer commented that the proposed work is focused on making cells and testing them. The reviewer added that presumably the authors had a goal of doing more of this during the project, which ends soon. The reviewer declared that is future work is desired here, additional development work is likely needed before committing resources to full cell evaluation is appropriate, and gave an example of working on making a solid-state cathode with the LLZO scaffold.

Reviewer 2

The reviewer noted that the next steps are to achieve full infiltration of the cathode, achieve high ionic and electronic conductivity of the cathode (the current organic cathode suffers from low electronic conductivity), and achieve the final targeted dimensions (membrane thickness and high porosity cathode scaffold, with desirable mechanical properties. The reviewer expressed that it will be challenging to achieve all of these metrics, but the focus on the cathode is a good one, and it is likely that meaningful progress will be made.

Reviewer 3

The reviewer stated that the planned future works is reasonable; however, since the cycling of the Li anode was not described, it is not possible to assess the likelihood of full cell cycling success.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer stated that the goal is to make a high-energy, solid-state cell, and this is relevant to VTO.

Reviewer 2

The reviewer commented that this is a valuable project to the VTO portfolio, providing process knowledge for solid-state batteries. It was unclear to the reviewer how likely it will be to achieve high energy density and rate capabilities (in line with DOE targets) within the timeframe of the remaining project.

Reviewer 3

The reviewer was not able to provide a yes/no answer as there was insufficient information. The reviewer explained that if the cell performance characteristics were disclosed, it would help provide a more definitive answer. The reviewer noted that ceramic electrolytes are heavier and more expensive than liquid electrolytes; thus, replacing liquid with ceramic electrolytes, especially in anode and cathode, will make it difficult to achieve Wh/kg metrics relevant to VTO. This is the reviewer's assessment based on the information provided in the poster.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer suggested that the resources are sufficient to achieve the project milestones.

Reviewer 2

The reviewer claimed that the resources appear to be sufficient.

Reviewer 3

The reviewer stated that this project would have made more progress with a higher budget. The reviewer added that going from a cell architecture concept to a prototype with $1M is a real challenge, and more resources would likely have led to more progress.

Acronyms and Abbreviations

3-D	Three-dimensional
Ah	Ampere-hour
Al	Aluminum
ANL	Argonne National Laboratory
APS	Advanced Photon Source
ARL	U.S. Army Research Laboratory
BNL	Brookhaven National Laboratory
BTFE	bis(2,2,2-trifluoroethyl) ether
CAM	Cathode active material
CAMP	Cell Analysis, Modeling, and Prototyping Facility
CE	Coulombic efficiency
CEI	Cathode-electrolyte interface
C-F	Carbon-fluorine bond
CFM	Complex framework materials
CIP	Contact ion pairs
cm	Centimeter
Co	Cobalt
CO_2	Carbon dioxide
COVID-19	Coronavirus disease 2019
Cu	Copper
DEMS	Differential Electrochemical mass spectroscopy
DFT	Density functional theory
DMC	Dimethyl carbonate
DOE	U.S. Department of Energy
EC	Ethylene carbonate
EERE	Office of Energy Efficiency and Renewable Energy
EIS	Electrochemical impedance spectroscopy
EPD	Electrophoretic deposition
EV	Electric vehicle
FEC	Fluoroethylene carbonate
FEC	Functional electrocatalysts

FEMC	Methyl 2,2,2-trifluoroethyl carbonate
FLHCE	Fluorinated localized high-concentration electrolyte
FY	Fiscal year
g	gram
GBA	γ-butyrolactone
GHG	Greenhouse gas
GM	General Motors
HRTEM	High-resolution transmission electron microscopy
INL	*Idaho National Laboratory*
Kg	Kilogram
kWh	Kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
LFP	Lithium iron phosphate
LHCE	Localized high-concentration electrolyte
Li	Lithium
LiF	Lithium fluoride
LiFSI	Lithium bis(fluorosulfonyl)imide
$LiPF_6$	Lithium hexafluorophosphate
Li-S	Lithium-sulfur
Li-TFSI	Lithium bis(trifluoromethanesulfonyl)imide
LLZO	Lithium lanthanum zirconium oxide
LSE	Localized saturated electrolyte
LT	Low-temperature
MA	Methyl acetate
mAh	Milliamp-hour
Mn	Manganese
MOC	Mesoporous ordered ceramic
MOF	Metal-organic framework
MP	Methyl propionate
N/P	Negative electrode to positive electrode capacity ratio
NA	$LiNi_{0.95}Al_{0.05}O_2$
NATM	Co- and Mn-Free $LiNi_{0.93}Al_{0.05}Ti_{0.01}Mg_{0.01}O_2$

Nb	Niobium
NC	$LiNi_{0.94}Co_{0.06}O_2$
NCA	Nickel cobalt aluminum oxide
NECST	Nanomaterials for Energy Conversion Storage Technology
Ni	Nickel
NM	$LiNi_{0.95}Mn_{0.05}O_2$
NMC	Nickel manganese cobalt oxide
NMR	nuclear magnetic resonance
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PDF	Pair-distribution function
PECVD	Plasma-enhanced chemical vapor deposition
PEO	Polyethylene oxide
PFPE	Perfluoropolyether
PI	Principal Investigator
PNNL	Pacific Northwest National Laboratory
POCs	Porous and mesoporous ordered ceramics
POFM	Porous organometallic framework materials
PTA	Polysulfide trapping additives
PVDF	Polyvinylidene difluoride
R&D	Research and development
RDD&D	Research, development, deployment, and demonstration
S	Sulfur
SEI	Solid-electrolyte interface
SEM	Scanning electron microscopy
Si	Silicon
SIMS	Secondary Ion Mass Spectrometry
SLAC	Stanford Linear Accelerator Center
SNL	Sandia National Laboratories
SoC	State of charge
SPAN	Sulfurized polyacrylonitrile
TEM	Transmission electron microscopy

TFEPE	1,1,2,2-tetrafluoroethyl n-propyl ether
Ti	Titanium
ToF	Time-of-Flight
TXM	Transmission X-ray microscopy
U.S.	United States
UCSD	University of California-San Diego
USABC	United States Advanced Battery Consortium
UT	University of Texas
V	Volt
Vhold	Voltage hold
VTO	Vehicle Technologies Office
Wh	Watt-hour
XRD	X-ray diffraction

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3. Energy Efficient Mobility Systems

The Vehicle Technologies Office (VTO) supports research, development, deployment, and demonstration (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. The office's investments leverage the unique capabilities and world-class expertise of the national laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies and systems (including automated and connected vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency and improvement); combustion engines to reduce greenhouse gas (GHG) emissions; and technology deployment and integration at the local and state level. In coordination with the other offices across the Office of Energy Efficiency and Renewable Energy (EERE) and the U.S. Department of Energy (DOE), the Vehicle Technologies Office advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

The Energy Efficient Mobility Systems (EEMS) subprogram supports research, development, and demonstration of innovative mobility solutions that improve the affordability, accessibility, and energy productivity of the overall transportation system. EEMS leverages emerging disruptive technologies such as connected and automated vehicles, information-based mobility-as-a-service platforms, and artificial intelligence-based transportation control systems to accelerate the transition to a zero carbon-emission transportation future. The EEMS subprogram also develops and utilizes large-scale transportation modeling and simulation capabilities to evaluate the impacts of new mobility solutions across multiple geographies and populations, ensuring that all Americans, especially underserved and energy communities, benefit from the development and deployment of clean transportation technologies.

The EEMS subprogram consists of two primary activities: Computational Modeling and Simulation, and Connectivity and Automation Technology. The subprogram's overall goal is to identify feasible system-level pathways and develop innovative technologies and systems that can dramatically improve mobility energy productivity (MEP) for individuals and businesses when adopted at scale. The EEMS subprogram has developed a quantitative metric for MEP, which measures the affordability, energy efficiency, convenience, and economic opportunity derived from the mobility system. The metric, while encompassing multiple vehicle classes and modes for passenger and goods movement, is used by the subprogram to evaluate success and by the transportation community to inform planning decisions. The EEMS subprogram's target is a 20% improvement in MEP by 2040 relative to a 2020 baseline.

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
eems013	Argonne National Laboratory Core Tools-Simulation	Phil Sharer (Argonne National Laboratory)	3-8	3.63	3.50	3.50	3.25	3.50
eems037	Big Data Solutions for Mobility	Jane Macfarlane (LBNL)	3-12	3.50	3.50	3.25	3.25	3.44
eems041	ANL Everything-in-the-loop (XIL) Capabilities	Kevin Stutenberg (Argonne National Laboratory)	3-16	3.25	3.42	3.25	3.08	3.31
eems061	Scaling up the Realtime Data, Simulation and Artificial Intelligence (AI) and Control for Optimizing Regional Mobility	Jiboananda Sanyal (Oak Ridge National Laboratory)	3-22	3.00	3.25	3.50	2.50	3.13
eems066	Livewire Data Platform-A Solution for Energy Efficient Mobility Systems (EEMS) Data Sharing	Lauren Spath-Luhring (National Renewable Energy Laboratory)	3-26	3.25	3.13	2.88	3.00	3.11

eems067	Virtual and Physical Proving Ground (VPPG) for Development and Validation of Future Mobility Technologies	Dean Deter (Oak Ridge National Laboratory)	3-30	3.50	3.50	3.63	3.33	3.49
eems082	Validation of Connected and Automated Mobility System Modeling and Simulation	Dhiren Verma (American Center for Mobility)	3-34	3.30	3.10	3.40	3.20	3.20
eems083	CIRCLES: Congestion Impact Reduction via Connected and Automated Vehicle (CAV)-in-the-Loop Lagrangian Energy Smoothing	Alexandre Bayen (University of California at Berkeley)	3-39	3.50	3.63	3.75	3.50	3.59
eems084	Energy-Efficient Maneuvering of Connected and Automated Vehicles (CAVs) with Situational Awareness at Intersections	Sankar Rengarajan (Southwest Research Institute)	3-43	3.13	3.50	3.38	3.25	3.36
eems089	Energy Efficient Connected and Automated Vehicles (CAVs), Workflow Development and Deployment	Dominik Karbowski (Argonne National Laboratory)	3-47	3.13	3.50	3.50	3.38	3.39
eems090	Applying Artificial Intelligence (AI) Based Signal Coordination and Controls for Optimized Mobility for the Nimitz Highway	Hong Wang (Oak Ridge National Laboratory)	3-51	3.17	3.33	3.50	3.33	3.31

eems092	Behavior, Energy, Autonomy, Mobility (BEAM) CORE	Anna Spurlock (Lawrence Berkeley National Laboratory)	3-55	3.50	3.50	3.50	3.25	3.47
eems093	Transportation System Impact: POLARIS Workflow Development, Implementation and Deployment	Joshua Auld (Argonne National Laboratory)	3-59	3.50	3.63	3.63	3.25	3.55
eems094	Development and Validation of Intelligent Connected and Automated Vehicle (CAV) Controls for Energy-Efficiency	Dominik Karbowski (Argonne National Laboratory)	3-63	3.25	3.50	3.50	3.50	3.44
eems095	Integrated Control of Vehicle Speeds and Traffic Signals for Reducing Congestion and Energy Use	Timothy Laclair (Oak Ridge National Laboratory)	3-67	3.50	3.17	3.33	3.17	3.27
eems096	Characterizing Behaviors and Capabilities for Emerging Connected and Automated Vehicle Technologies, Sensors, and Connectivity	Thomas Wallner (Argonne National Laboratory)	3-70	3.33	3.67	3.17	3.00	3.44
eems097	Micromobility-Integrated Transit and Infrastructure for Efficiency (MITIE)	Andrew Duvall (National Renewable Energy Laboratory)	3-74	3.25	3.38	3.38	3.25	3.33
eems098	Optimizing Drone Deployment for More Effective Movement of Goods	Victor Walker (Idaho National Laboratory)	3-78	3.33	3.33	3.17	3.33	3.31

eems099	Metrics for Assessing the Impacts of Energy-Efficient Mobility Systems	Venu Garikapati (National Renewable Energy Laboratory)	3-81	3.50	3.50	3.63	3.38	3.50
eems100	Dynamic Curb Allocation	Chase Dowling (Pacific Northwest National Laboratory)	3-85	3.17	3.17	3.33	2.83	3.15
eems101	RealSim, An Anything-in-the-loop Platform for Mobility Technologies	Dean Deter (Oak Ridge National Laboratory)	3-88	3.30	3.30	3.40	3.10	3.29
eems102	AI-Engine for Optimizing Integrated Service in Mixed Fleet Transit Operations	Philip Pugliese (Go Carta)	3-93	3.25	3.25	3.25	3.00	3.22
eems103	Transit-Centric Smart Mobility System for High-Growth Urban Activity Centers: Improving Energy Efficiency through Machine Learning	Jinhua Zhao (Massachusetts Institute of Technology)	3-96	3.00	4.00	2.50	3.00	3.44
eems104	Increasing Affordability, Energy Efficiency, and Ridership of Transit Bus Systems through Large-Scale Electrification	Ziqi Song (Utah State University)	3-98	3.00	3.50	3.50	3.00	3.31

eems105	Energy Optimization of Light and Heavy Duty Vehicle Cohorts of Mixed Connectivity: Automation and Propulsion System Capabilities via Meshed Vehicle-to-Vehicle (V2V)-Vehicle-to-Infrastructure (V2I) and Expanded Data Sharing	Darrell Robinette (Michigan Technological University)	3-100	3.33	3.50	3.58	3.25	3.44
eems106	Developing an Energy-Conscious Traffic Signal Control System for Optimized Fuel Consumption in Connected Vehicle Environments	Mina Sartipi (University of Tennessee)	3-106	3.50	3.25	3.50	3.38	3.36
eems107	Improving network-wide fuel economy and enabling traffic signal optimization using infrastructure and vehicle-based sensing and connectivity	Joshua Bittle (University of Alabama)	3-110	3.17	3.25	3.25	3.17	3.22
eems108	Co-Optimization of Vehicles and Routes	Jack Schneider (PACCAR)	3-116	3.17	3.00	3.00	2.50	2.98
eems109	Connected and Learning Based Optimal Freight Management for Efficiency	Ali Borhan (Cummins)	3-119	3.17	3.33	3.50	3.17	3.29

eems110	Human Factors and Technologies Design to Improve User Acceptance of Pooled Rideshare (PR) for Increasing Transportation System Energy Efficiency	Yunyi Jia (Clemson University)	3-122	3.00	3.00	3.13	2.75	2.98
eems111	Contextual Predictions and Eco Services for Electrified Vehicles	Jacopo Guanetti (AV-Connect, Inc.)	3-127	3.00	3.17	3.17	2.83	3.08
eems112	National Renewable Energy Laboratory Core Modeling & Decision Support Capabilitie s, Route Energy Prediction Model (RouteE), Future Automotive Systems Technology Simulator (FASTSim), OpenPATH, and Transportation Technology Total Cost of Ownership (T3CO)	Jeff Gonder (National Renewable Energy Laboratory)	3-130	3.00	3.17	3.00	3.33	3.13
Overall Average				**3.29**	**3.36**	**3.37**	**3.17**	**3.32**

Presentation Number: eems013
Presentation Title: Argonne National Laboratory Core Tools-Simulation
Principal Investigator: Phil Sharer, Argonne National Laboratory

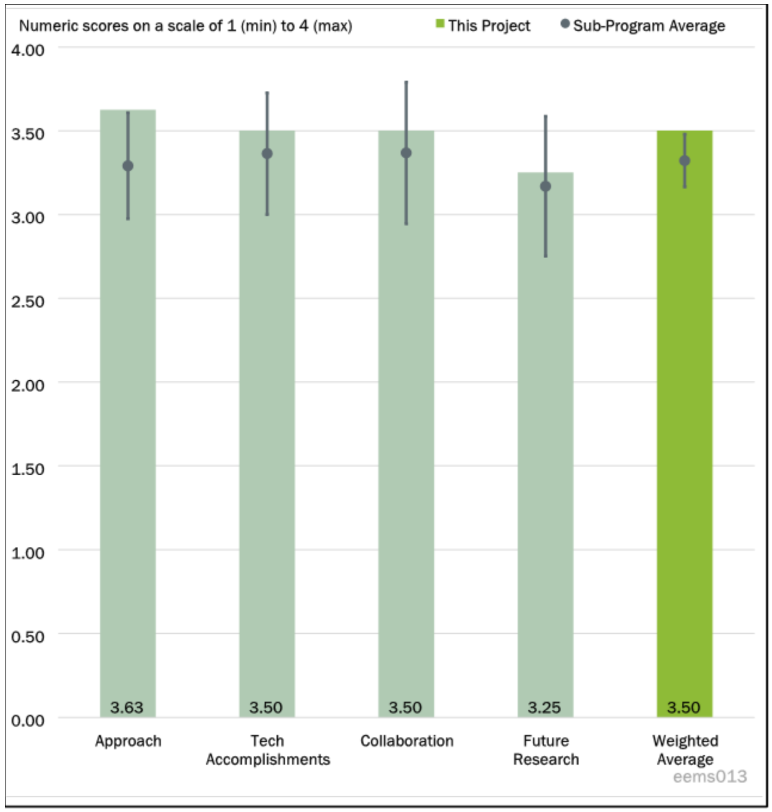

Figure 3-1 - Presentation Number: eems013 Presentation Title: Argonne National Laboratory Core Tools-Simulation Principal Investigator: Phil Sharer, Argonne National Laboratory

Presenter

Phil Sharer, ANL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer noted that there are no flaws in the overall approach, but there are misgivings about the nature of the research, i.e., software development. There are no commercial software available that can do a similar job, which eases but does not entirely eliminate these misgivings . The list of contributors to the project on the title page numbers 13 is impressive.

Reviewer 2

The reviewer expressed that the barriers being addressed by this project are very important and the overall scope and design of the project help to support and streamline the efforts of many downstream efforts.

Reviewer 3

The reviewer felt that the project is focused on development of core simulation tools, supporting many other projects in the EEMS program. The technical barriers will be addressed because the project relies on further development of the AUTONOMIE model which is very popular across original equipment manufacturers (OEMs), and automotive R&D institutions. Moreover, the proposed, computationally efficient version of AUTONOMIE, which will be less dependent on other software modules, is very important for stakeholders addressing the listed technical barriers.

Reviewer 4

The reviewer commented that the project approach is sound. The AMBER framework is designed to support model-based systems engineering simulation workflows. AUTONOMIE continuously collects data and inputs from public and private sources.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer said that developing Autonomie Lite and Autonomie Express is a great idea, and could perhaps result in the adoption of the tool by a much larger audience, resulting in greater feedback and ideas for further improvement.

Reviewer 2

The reviewer stated that the conglomeration of many different tools in the project is very impressive. Given the presentation, the project team seems to be making technical progress across each of the tools described. The reviewer especially appreciated the explicit inclusion of improvements to the workflow that is directed at stakeholders.

Reviewer 3

The reviewer stated that the technical progress is impressive and well planned, as evident in development of Autonomie Lite and Autonomie Express. The team targets two releases per year, while maintaining an increasing number of models and interfaces. The team uses best practices for software development and testing, while listening and taking into account stakeholder input.

Reviewer 4

The reviewer commented that three new Autonomie packages were introduced (Lite, Express, and AI). Autonomie was updated to support VTO studies on new and emerging technologies.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer expressed that the large number of DOE projects that rely on this project is proof that there is outstanding collaboration and relevance to the DOE objectives.

Reviewer 2

The reviewer stated that the project team does a nice job of showing the use of the core models and tools across stakeholders in Slides 21 and 22. However, it would also be useful to see an explicit description of the collaboration between developers of the various modeling tools themselves, and steps the project team is taking to help streamline the integration of different models. Lastly, it would be good to see the iterative feedback process among users of the models (especially at the national labs) that may lead to better streamlining or improvements to tools developed by the project team.

Reviewer 3

The reviewer stared that the core tools are well-integrated across multiple projects and government agencies; therefore, the reviewer views the collaboration and coordination within the team as good.

Reviewer 4

The reviewer observed that the project team demonstrates a very broad span of collaboration with numerous government and private partners (too numerous to list here) for model development, simulation, workflows and database creation.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer stated that the proposed future research is designed to improve the tool chain and processes.

Reviewer 2

The reviewer noted that improvement of future technical work is laid out nicely in Slide 23. However, as these models become increasingly popular among external stakeholders, the team should begin putting explicit emphasis on accessibility. The team mentions licensing, documentation, and training, which will all contribute to accessibility, but other issues as identified in the session such as open-access (e.g., over licensed back-end features such as MATLAB) would be very helpful as well.

Reviewer 3

The reviewer expressed that the proposed next steps are articulated in detail with high likelihood of achieving the targets. The development of AI is of special interest as it promises to decrease computational complexity while maintaining simulation fidelity through data-driven methods.

Reviewer 4

The reviewer found that the proposed future work on Aeronomie development, as well as further development on the Autonomie model and diverse workflows, is well-motivated and will be immensely useful.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

In referencing the response to the previous Collaboration and Coordination question, the reviewer reiterated that the large number of DOE projects that rely on this project is proof that there is outstanding collaboration and relevance to the DOE objectives.

Reviewer 2

The reviewer expressed that the project aligns with VTO objectives.

Reviewer 3

The reviewer noted the clear relevance of this project to the overall VTO subprogram objectives as project goals are defined in the development of core tools. The reviewer had no further comments.

Reviewer 4

The reviewer stated that the project supports the overall VTO subprogram objectives by creating a versatile suite of modeling tools and databases that support stakeholder engagement, large scale vehicle studies, diverse vehicle types, and evaluation/assessment of new vehicle technologies.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer commented that there is a lot more to be done in this area, and as a result, it could be stated that the resources are insufficient. However, the reviewer has seen some of the work that has been done for U.S.

DRIVE (Vehicle-Mobility Systems Analysis Technical Team) and the results of those simulation are providing very interesting insights into future mobility. The reviewer further observed that these processes and the toolchain can go a long way in helping understand the issues and ramifications of mobility choices.

Reviewer 2

The reviewer determined that the amount of funding seems reasonable for the scope and size of the project.

Reviewer 3

The reviewer felt that the project has sufficient resources to achieve its goals. The project team illustrated how it supports a number of important projects as listed.

Reviewer 4

The reviewer commented that the approved funding for the three year project is appropriate for this effort.

Presentation Number: eems037
Presentation Title: Big Data Solutions for Mobility
Principal Investigator: Jane Macfarlane, Lawrence Berkeley National Laboratory

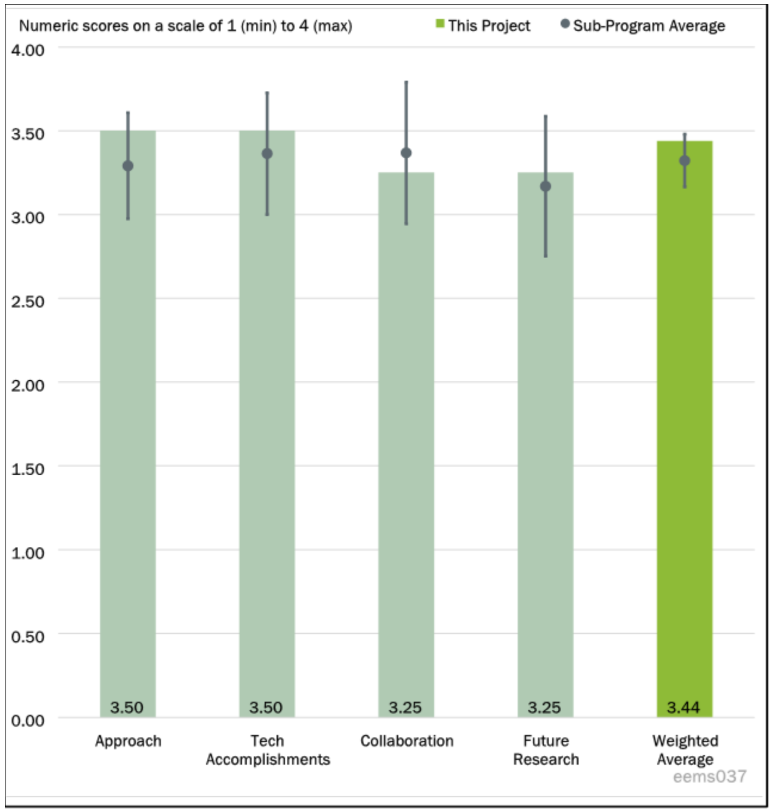

Figure 3-2 - Presentation Number: eems037 Presentation Title: Big Data Solutions for Mobility Principal Investigator: Jane Macfarlane, Lawrence Berkeley National Laboratory

Presenter

Jane Macfarlane, LBNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer determined that the barriers laid out in Slide 2 are definitely an important issue facing planners and operators of transportation systems. If generalizable, this project has the potential to help improve the transportation system in a variety of ways.

Reviewer 2

The reviewer responded that the approach is addressing technical barriers related to the ability to conduct realistic metropolitan level transportation modeling in a timely manner so that a variety of scenarios can be studied. The technical barrier of making a more simplistic and computationally less sophisticated version of the tool for transportation planning practitioners is also being addressed. This is important since it is unrealistic for transportation planning agencies to have the resources available for supercomputers.

Reviewer 3

The reviewer asserted that the approach of using the origin-destination data from a transportation planning organization to start the model and then calibrate it using Wejo is a manageable approach when working on regional-scale projects. This can potentially be applied to other cities, as was mentioned in the presentation for San Francisco to Sacramento and Los Angeles to the border.

Reviewer 4

This reviewer commented that the project addresses large-scale regional traffic dynamics with the design of active control strategies for managing regional movement. In designing these strategies, the project team aims to be socially aware on metrics for transportation, and to understand how signal control variations and timings will enable greater impact.

The approaches are to extend and improve Mobiliti (a transportation modeling platform), use AI to build transferable models after their creation on a high-performance computer and provide to organizations that do not have high-performance computing (HPC) access, and enable practitioners to run these reduced models to develop new kinds of control and planning solutions.

The barriers include the increased complexity of city-level transportation to model at scale in reasonable time, challenges to acquiring sensor data, and the difficulties in optimization to scale. By aiming to model cities at scale with HPCs and search for reduced order models, these barriers are effectively addressed. There may be additional challenges remaining in understanding under what circumstances the models can be reapplied and how they may be used in other simulation environments.

*Question 2: **Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.***

Reviewer 1

The reviewer commented that Slide 6 provides a nice overview of the progress made in the last period of work. The accomplishments of the research team are very impressive, especially on the technical development of the model and digestion of big data.

Reviewer 2

The reviewer believed that the project team has made good progress and has successfully run the large scale HPC model of San Francisco using Mobiliti. The reviewer was not entirely clear on how close the team is to completing a successful surrogate model (Task 3). The team is, however, making progress on the traffic signal control algorithms.

Reviewer 3

The reviewer stated that the project team presented uncertainty Slides very well. The extension of the traffic controller optimization work going from one intersection, to a corridor, and to the grid is great. This is a challenging problem. It will be great to see the complexity and performance at the grid level.

The reviewer did describe a couple of concerns. First, the long term project goal is to generate surrogate models for practitioners. It was not clear to the reviewer how feasible this goal is in terms of the computational needs as well as the learning curve. Second, with Wejo having less than 2% penetration, the reviewer suggested that there needs to be a study on how accurate the calibrated model will be. The reviewer further stated that a comparison between a model calibrated using only Wejo and another model calibrated/built using other existing internet-of-things devices in San Francisco would be highly valuable

Reviewer 4

The reviewer confirmed that the technical approaches in this project reporting period are explored with tasks in: 1.) data acquisition and cleaning, 2.) uncertainty quantification, 3.) surrogate model building, 4.) design of signal controllers, and 5.) establishing city-level metrics. The city models include the Bay Area, LA Basin, and new data from Sacramento are being explored.

For the surrogate model building and data acquisition, the reviewer inquired whether the fuel estimates come from reading the vehicle data directly, or from extrapolating from the global positioning system of vehicle motion? The researcher's Slides mention 1-5Hz, but if using vehicle data in this way, the resolution on acceleration (or even approximating acceleration/velocity from position) may not have high enough resolution to build an energy model that could be used in large-scale simulators. Additionally, such an energy model might exhibit characteristics that would encourage overfitting by model users who apply it in AI contexts.

For the fuel validation, the reviewer wondered what the error bounds are on approximation of the model, and how this compares with potential overall savings (i.e., are the potential savings much greater than the error bounds of the model)?

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer intimated that it is difficult to judge the collaboration and contributions of the partner institutions and stakeholders, since no details are provided on Slide 20. The reviewer recommended that the project team be more explicit on the tasks and accomplishments amongst the labs, and describe how they are coordinating. Additionally, it would be helpful to list the contributions/relationships of the stakeholders to understand how they are linked with the project (helping with data/modeling versus as an endpoint for information dissemination).

Reviewer 2

The reviewer stated that the project team has a large number of members; however, the roles, and collaboration and cooperation of each member is not entirely clear.

Reviewer 3

The reviewer believed that this is a great group consisting of three national labs (Lawrence Berkeley National Laboratory [LBNL], Argonne National Laboratory [ANL], and the National Renewable Energy Laboratory [NREL]) as well as public (City of San Jose) and private partners. The partnership with Siemens and Wejo are very relevant.

Reviewer 4

The reviewer commented that the project team collaboration is strong, and that project tasks are distributed among team members.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer mentioned that most of the future work focuses on the technical aspects of the modeling, but it may serve the project well to explicitly have goals on outreach and engagement with existing and new stakeholders. To that end, statements on future goals for expected outcomes in project team interactions with stakeholders would be useful as well.

Reviewer 2

The reviewer expressed that future work will include getting the surrogate model in place. Implementing the data driven energy estimates will also be included in the future work. One element that was not clear to the reviewer from the future work description is how the HPC Mobiliti model results are going to be compared with the surrogate model results. If the transportation planning organizations are supportive of the HPC

Mobiliti model as an approach, they will need to be comfortable that the surrogate model is producing consistent (although higher level, more aggregate) results.

Reviewer 3

The reviewer's only concern was that considering 70% of the project is reported to be done, and the end date is January 2023, the remaining amount of work is significant.

Reviewer 4

The reviewer mentioned that the next phase of the research is to improve the surrogate model and explore ways to perform estimates at a larger level.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer commented that the project aligns with VTO objectives.

Reviewer 2

The reviewer affirmed that this project is relevant to EEMS by developing tools for a metropolitan area to assess transportation strategies that help address energy and equity considerations.

Reviewer 3

The reviewer remarked that developing tools to model large-scale transportation networks using real-world data is relevant to the VTO objectives. While, the goal is to make the tools rapidly, the project team did not define how many resources will be required for this rapid pace. The reviewer further concluded that it would be beneficial for the researchers to mention how long it may take to build and update the model given the resources usually accessible to practioners

Reviewer 4

The reviewer observed that the project provides strong relevance for understanding energy use at large scales in mobility applications.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer determined that the budget of the project seems reasonable relative to the size of the project and effort required across three labs.

Reviewer 2

the reviewer concluded that the resources appear to be sufficient for the project to meet its goals.

Reviewer 3

The reviewer asserted that the project team has sufficient resources to deliver the project.

Reviewer 4

The reviewer felt that the budget is commensurate with efforts and expected results.

Presentation Number: eems041
Presentation Title: ANL Everything-in-the-loop (XIL) Capabilities
Principal Investigator: Kevin Stutenberg, Argonne National Laboratory

Presenter

Kevin Stutenberg, ANL

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

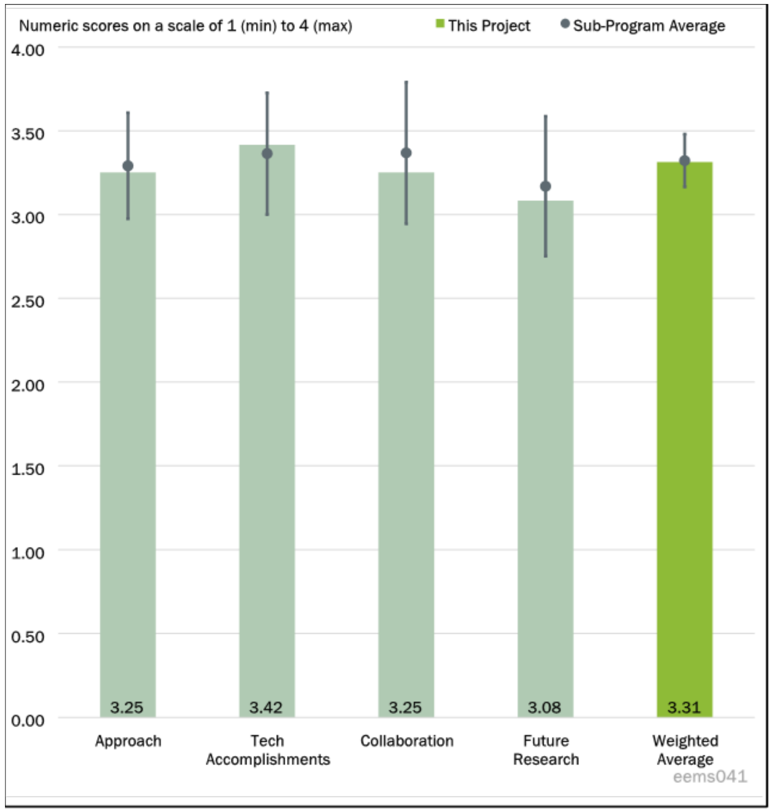

Figure 3-3 - Presentation Number: eems041 Presentation Title: ANL Everything-in-the-loop (XIL) Capabilities Principal Investigator: Kevin Stutenberg, Argonne National Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer stated that the project develops key technology enablers that underlie research on connected and automated vehicles (CAVs). It does an excellent job of applying different software and hardware strategies to achieve the desired goals (data collection, controls implementation, and vehicle performance characterization).

Reviewer 2

The reviewer expressed that there are a number of pieces in this project so it is difficult to evaluate all of the technical barriers. The team has good experience and knowledge in the areas needed and this should enable the project to move forward in a timely manner. The selection of the new vehicles is good/appropriate, but bringing on three new vehicles and integrating vehicle controls is a significant challenge.

Reviewer 3

The reviewer suggested that there is a need for new testing and evaluation capabilities for connected and autonomous vehicles and the team's approach to developing next generation research platforms, expanded dyno XiL workflows and Lab2Road, is sound.

Reviewer 4

The reviewer intimated that experimental work is extremely costly and time consuming. Having the ability to put the CAV in an XiL environment to run scenarios virtually is paramount to achieving market acceptance and validation of behaviors. This seems to be a converging approach by research labs, OEM's and tier 1 suppliers.

Reviewer 5

The reviewer determined that overall, the researchers have defined the barriers very clearly. Making the XiL work for any vehicle is challenging as stated in the presentation. Adding a variety of vehicles that the project team has access to through the U.S. Department of Transportation (DOT) helps with increasing the portfolio of vehicles implemented and tested. It is important to test both dedicated short-range communications (DSRC) and cellular vehicle-to-everything (C-V2X).

Reviewer 6

The reviewer stated that the project is a synergetic effort by different DOE laboratories (e.g., ANL, Oak Ridge National Laboratory [ORNL], LBNL) for developing advanced XiL modeling and testing platform for CAV related research. The entire project is well designed and aligns with other parallel projects. The reviewer believed that the timeline for Core2 makes sense.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer commented that a number of impressive technology demonstrations has been carried out (virtual vehicle interacting with real vehicle, etc.) under the project. The progress has been in line with the project plan, which is impressive whenever you are dealing with hardware/software implementations.

Reviewer 2

The reviewer stated that the project is on plan for development, integration, and demonstrations. The reviewer has no significant concerns at this point. The reviewer also commented that Slide 11 describes an appropriate selection of vehicles, but questioned whether every vehicle integration a one-off. Per Slide 12, the reviewer inquired how the results are being used? That is, is the project teambuilding virtual models for the latency, controller, and dynamics that then will be integrated into the vehicle models and/or used for controls development and tuning?

Reviewer 3

The reviewer felt that the team has made significant progress on the vehicle-in-the-loop (VIL) milestones, such as enabling hardware connectivity, demonstrating powertrain overrides, etc. The team has made solid progress on XiL milestones such as selection of fiscal year 22 research platforms and XiL vehicle integration on the Sonata hybrid electric vehicle (HEV).

Reviewer 4

The reviewer commented that the project seems to be on track with the operation of vehicles on the dynamometer and correlated to real world behavior. Obviously, COVID impacted nearly all projects and progress, but it appears the team has made good strides to the project plan regardless.

The reviewer felt that the acquisition of results is timely and highly relevant to other projects sponsored by DOE in the EEMS area.

Reviewer 5

The reviewer expressed that the team has accomplished quite a bit with developing and demonstrating XiL workflow.

Reviewer 6

The reviewer noted that the aerodynamic load evaluation is very interesting, which can address the existing research gaps to some degree on this effect. The results will be useful for further energy/emissions analyses. Based on the reviewer's understanding, the test was conducted for three light-duty vehicles. If so, a test plan for heavy-duty trucks would be preferable too. Just for informational reference, California Partners for Advanced Transportation Technology (PATH) used to perform some real-world truck platooning testing in Canada to evaluate the aerodynamic load effects due to different intra-platoon gaps. The reviewer did have one question about the modeling and testing capability—can the current platform conduct lateral behavior related experiments?

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer stated that project collaboration includes USDOT, a university, and various national labs with expertise relevant.to the project tasks. The project tasks require good intra-organizational collaboration between these entities and is working well.

Reviewer 2

The reviewer commented there is good collaboration between the modeling and hardware teams. The reviewer also stated that is good to see the partnership with GM being leveraged. The project team should continue to explore other initiatives, including those with USDOT.

Reviewer 3

The reviewer observed that the team has shown strong collaboration with the DOE national labs (ORNL and LBNL), Ecocar Challenge, as well as outside partners such as the National Highway Traffic Safety Administration (NHTSA), Virtual Open Innovation Collaborative Environment for Safety (VOICES), Illinois Institute of Technology (IIT), and University of California-Irvine.

Reviewer 4

The reviewer commented that the collaboration and integration with other federal institutions and DOE EEMS projects is strong and provides great justification for the project objectives and outcomes. The reviewer liked the usages of other EEMS projects for vehicle data for validation of modeling.

Although not explicitly stated on the slides, and not mentioned during the presentation, the reviewer stated it would be good to get the OEM's, Ford, Hyundai, etc. more involved with ANL, ORNL, and others on proprietary controlled area network (CAN) signals that aid in the collection of data and determining how the vehicle and powertrain are behaving. While much of this data are proprietary, it would certainly help reduce effort for reverse engineering the signals that occur anyway.

Reviewer 5

The reviewer stated that the team mostly consists of ANL researchers and one graduate student from IIT.

The U.S DOT NHSTA provides vehicles for the project. However, the role of VOICES cooperative automation research mobility applications (CARMA) is not clear in this project.

Reviewer 6

The reviewer observed that the coordination with other DOE national laboratory partners is well addressed in the project. It is noted that the Federal Highway Administration (FHWA) CARMA and VOICES program efforts have been recognized, which should benefit the project Core2 very well, from both the real-simulation interaction and system scalability perspectives. The team needs to consider involvement of industry.

Question 4: Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1

The reviewer remarked that the next steps are appropriate extensions of the previous work. The researchers acknowledge certain difficulties (increasing over time) in implementing certain controls linkages in production vehicles.

Reviewer 2

The reviewer expressed that the progress presented in the different aspects of the project is all significant. However, the researchers will need to manage the challenges with integration. The reviewer questioned whether every vehicle integration is a one-off? Going forward the team should look for ways to commonize this or leverage other efforts.

For the aerodynamic load evaluation, the reviewer questioned whether there is plan to conduct an "extensive test matrix with different vehicle placements, vehicle configurations, speed, and gaps" within one week of testing and if so, is this reasonable, Further, the reviewer asked what the repeatability of the tests and noise factors are versus the expected road-load reduction? From these, can the team determine whether the measurements provide a relative significant difference and how many test repeats will be needed?

Reviewer 3

The reviewer believed the proposed future work, including additional XiL vehicle integration, improving and expanding XiL workflow, and the initiation of Lab2Road, is very well-motivated.

Reviewer 4

The reviewer stated the HEV and plug-in hybrid electric vehicle (PHEV) vehicle platforms seem the most likely candidates to benefit from CAV technology and XiL workflow for energy savings. Limited energy savings (in terms of real kJ) will be achieved for BEVs in most scenarios. The HEV and PHEV applications can have significant energy reductions through CAV prediction horizon forecasts. The reviewer is excited to see how the proposed platforms from battery electric vehicle (BEV) to PHEV illustrate this point.

Reviewer 5

The reviewer commented that the objective of the project is defined as: "Develop an experimental platform and processes which can quantify vehicle-level energy use impacts of connected and automated vehicles (CAVs) for use in model validation, data collection and direct analysis of future mobility technologies." The type of override that can be executed and the type of studies that can be conducted depend on the vehicles, on-board modules, and other factors. The team plans to expand the XiL research fleet. While this is a good approach, the reviewer questioned whether this will be able to cover the existing vehicles? The reviewer asked how many and how often vehicles will need to be added to the fleet?

Reviewer 6

The reviewer mentioned that most of the proposed future work makes sense. Regarding the integration of research vehicles, the team may consider other powertrains (e.g., pure electric). Also, the team could consider extension to multi-laboratory or multi-institute collaborative platforms as another major future step?

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer felt the project is highly relevant to EEMS CAV activities and the general VTO research related to improving vehicle energy efficiency.

Reviewer 2

The reviewer expressed the project contributions coupling modeling, simulation, and testing that verify energy models and energy reductions from CAV technologies are very important outcomes.

Reviewer 3

The reviewer commented that the project is relevant to VTO subprogram objectives by providing a sound experimental framework for testing and evaluating relevant technologies for CAVs.

Reviewer 4

The reviewer stated that the project supports program objectives by providing the ability to examine CAV scenarios through an XiL facility. The XiL approach enables better control of conditions and environmental boundaries for determining the effectiveness of CAV technologies at scale and real-time implementation capability.

Reviewer 5

The reviewer said this project is directly relevant. Current methods of energy consumption measurement do not apply to connected and/or automated vehicle technologies, Advanced methods for experimentation are required to directly evaluate emerging mobility technologies and enable validation of DOE simulation efforts.

Reviewer 6

The reviewer mentioned that similar to other funded projects on modeling and testing platform development, this project supports the overall VTO subprogram objectives (e.g., EEMS). The successful completion of this project leverages DOE's capability on evaluating the energy impacts of emerging transportation technologies, such as connected and automated vehicles.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer noted that project progress is very good and milestones appear to be on track.

Reviewer 2

The reviewer intimated that there are many different activities that need to be coordinated. As a reviewer, it is difficult to judge whether there are sufficient resources for this project.

Reviewer 3

The reviewer stated that the approved funding for 2 years is appropriate.

Reviewer 4

From what was presented, the reviewer concluded that a lack of resources is not going to be an issue for this project. Collaboration with multiple labs, federal agencies, etc., and the already existing facilities (both physical and analytical) should provide the team with continued success and momentum to accomplish the project in the proposed time frame.

Reviewer 5

The reviewer commented that ANL and this team specifically have sufficient resources to deliver the project.

Reviewer 6

The reviewer felt that the project team leverages the key resources from DOE national laboratories, which should be sufficient for project objectives. The team is encouraged to get more involved with industry and explore additional resources related to the project.

Presentation Number: eems061
Presentation Title: Scaling up the Realtime Data, Simulation and Artificial Intelligence (AI) and Control for Optimizing Regional Mobility
Principal Investigator: Jibonanda Sanya, Oak Ridge National Laboratory

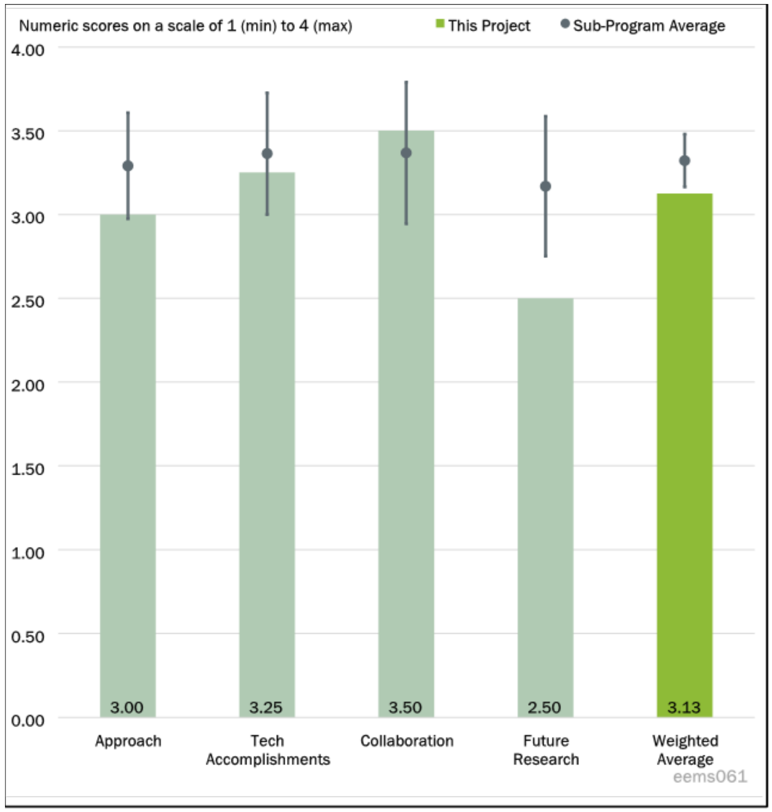

Figure 3-4 - Presentation Number: eems061 Presentation Title: Scaling up the Realtime Data, Simulation and Artificial Intelligence (AI) and Control for Optimizing Regional Mobility Principal Investigator: Jibonanda Sanya, Oak Ridge National Laboratory

Presenter

Jibonanda Sanya, ORNL

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer cited the following statements made by the presenter: 1.) “Different controller versions are deployed throughout the city;” 2. “For all experiments to date, the intersections had Siemens m60 controllers:” and 3.) “As we scale up, many intersections have m50 controllers, with different software versions. This will require changes in communication.” In reference to these statements, the reviewer commented that all of the improvements showcased by the project goals require clear communication between the different functions. Having different software versions in many data inputs/functions (e.g., different controllers) might result in a suboptimal system. The reviewer asked how could this be improved given limited resources, future expansions of these inputs, and additional potential versions?

Reviewer 2

The reviewer stated that the overall approach described in the introductory graphic is informative to understand the overall vision of the project, but some of the more detailed approach steps are a bit unclear and may be evolving as data streams and controllers are integrated into the CTwin approach. For example, quite a few traffic signal control algorithm developments are highlighted, but it is not necessarily clear if/how ramp metering and other control methods are to be integrated into the overall regional approach. The value of situational awareness is highlighted as well, but dynamic routing or other approaches are also not mentioned in significant detail. It is not clear if this is an issue of project scoping or if these strategies will be developed in the later stages of the project (or if they are even needed for the overall project goals). Any insights regarding the balance between sensor ingestion difficulty and benefits to overall system optimization could also be a useful addition to this work as traffic engineers may struggle with trade-offs such as purchasing supplemental probe data or upgrading traffic sensing at certain intersections. It seems the simulation component of this project may also be used to help understand some of these priorities.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer said the way the data has been integrated is a great accomplishment by itself. The final reporting should include lessons learned in this process.

Reviewer 2

The reviewer expressed that the highlighted accomplishments have been provided within the separate subtasks of the project, but the pieces still feel a bit independent and not contributing to the overall 20% regional energy reduction goals stated in the introduction. While situational awareness is important, typing the awareness into more advanced controls and routing seem to be implied, but not necessarily fully implemented at this point in time. Given the ambitious scale of the data ingestion related to this project, this result may be expected, but insights related to the controls developed and validating new usage possibilities afforded by these large scale techniques should be considered equally important to the overall project scope and a completion date of December 2022. For the example results shown, it is not clear if the results shown are truly optimal, or if more improvements are expected; this is important given the disparity between the targets and current examples of energy reduction as well as the discrepancies between the average and the daily example shown. A better description of the connections between this project’s situational awareness and proposed controls developed would also be helpful to understand the intended vision and progress of the overall progress. Specifically, is more situational awareness needed to get closer to the original goals, or is a scale-up of the methods a more promising direction for larger improvements? The publications and results from the AI-based signal control algorithm development are promising and support contributions from other EEMS projects. The project team may also find it beneficial to coordinate insights with the EEMS090 project team.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer observed that the project team’s coordination with multiple groups and stakeholders seems to be well orchestrated and managed.

Reviewer 2

The reviewer remarked that researchers presented a strong mix of collaborators in support of this project. While more information about the specific contributions of the different project partners would be helpful, the range of strong partners is highlighted. The researchers could also describe the interface between the lab contributions in more detail, but again this is a suggestion for improving the already strong collaboration highlighted for this work.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer intimated that the proposed research seems to tackle several of the barriers; however, the reviewer also thought that a clearer mapping of these needs/barriers addressed by the future research is preferred.

Reviewer 2

The reviewer indicated that more detail would be helpful for some of the future work scale up related items. The overall number of control signals and types used for the large-scale implementation mentioned for 2022 work would be helpful to understand the size of the envisions increase in scale. The reviewer also thought it would be useful to know if this scale-up is on the order of 10s or 100s of signal controllers; further, the reviewer asked whether there are any related concerns about scalability of the chosen controls optimization approaches as the problems become increasingly large. The "deploying traffic control algorithms in the field based on available controllers and data sources covering 80% control points" would imply 100s of signals to be controlled, but that is not entirely clear from the information and discussion provided in the presentation. Ultimately, the reviewer felt it would be helpful to clarify the expected outcomes for the end-stage of this specific project effort as a 20-year timeline was verbally mentioned in the context of the project's stated 20% regional improvement goal. For the scale-up of the classification algorithms, the reviewer wondered whether this represented a larger-scale data stream for the CTwin Data Lake only, or if there are additional control strategies that are also anticipated to utilize this information for regional control. For the incident detection efforts, it may be helpful to discuss methods with the EEMS037 project team since that project's incident detection methods have also shown promising results and a collaborative opportunity may exist for both projects. Integration of the incident detection algorithms may also be beneficial to the project's routing and controls goals, but the connection is not clear and if it is in scope at this point.

Given the described Shallowford Rd results showing a weekly average consumption reduction of 4.6% versus the intended goal of 20%, the reviewer believed it would be helpful to clarify how the future work portion of these efforts will move the overall benefits closer to the original targets. Specifically, is an increase in scope expected to dramatically improve overall energy benefits, or will additional controls such as routing and dedicated lanes be needed to achieve a larger improvement in energy reduction at the regional scale? Also, since the largest benefits in travel time reduction appear during off-peak hours, does the research team have any further insights about overall travel time impacts changing over the increase in scale. While the expanded experimental data will be informative to the overall project benefits and impacts, the scope of the intended experiments could be provided in a bit more detail to contrast what will be simulated with the expanded regional simulation.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer commented that developing these type of data and algorithms will assist in the development of more efficient energy mobility systems. The reviewer also felt it would be good to add a section on how the results will be translated from research to practice. The project is more of a research pilot, but in order for full dissemination several other components are needed.

Reviewer 2

The reviewer stated the overall goal of improved situational awareness is a key enabler for more intelligent overall system control and strategy implementation. The project's stated goal of 20% regional energy reduction is also in line with EEMS goals. The balance between travel time reduction and energy discussed in the presentation fits with the balancing of different EEMS outcomes.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer concluded that for the level of this pilot project, the resources seem sufficient. However, if this was a larger pilot (more locations added), additional funds would be needed.

Reviewer 2

The reviewer offered that resources seem adequate, although significant effort appears to have been spent on the difficult challenge of getting the data ingested and the CTwin Data Lake system functioning. With this in mind, some degree of supplemental funds may be needed for later stages of project scale-up, experiment execution, and analysis, if preliminary results support more investment.

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

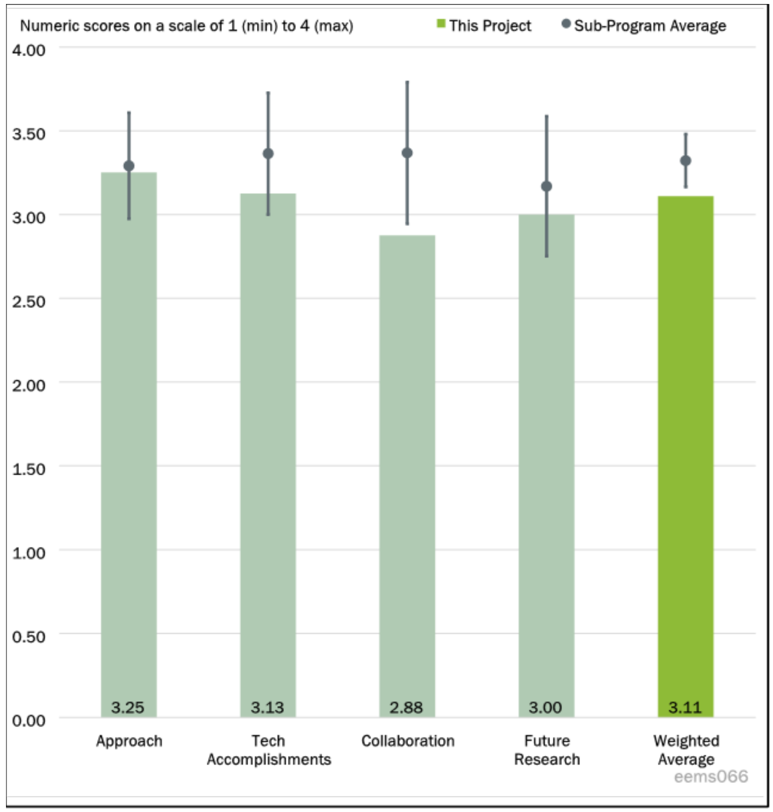

Figure 3-5 - Presentation Number: eems066 Presentation Title: Livewire Data Platform-A Solution for Energy Efficient Mobility Systems (EEMS) Data Sharing Principal Investigator: Lauren Spath-Luhring, National Renewable Energy Laboratory

Presenter

Lauren Spath-Luhring, NREL

Reviewer Sample Size

A total of six four evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer commented that overcoming the technical barriers identified by this project on Slide 2 will be a great boon to countless stakeholders in the field of transportation. Access to data absolutely levels the playing field for modelers, planners, etc.; and the work thus far demonstrates the project team's capability to address the technical barriers and even expand the scope of the work.

Reviewer 2

The reviewer observed that this project is not research but serves a very important function of supporting research platform development. The main technical barriers of launching Livewire and improving its capabilities for expanding the community of stakeholders are addressed very well. The milestones of the project plan for this FY look well thought out. While Livewire is serving the EEMS and VTO funded projects for now (data sharing), the plan is to continue expanding beyond National Lab projects.

Reviewer 3

The reviewer believed the team's approach is to collaborate on building a data platform with large-scale user impact by expanding access to more users, growing the features catalog, and providing good support to users.

Reviewer 4

The reviewer cited several strengths for the project. First, the development of the Livewire platform was based upon existing, successful data platforms. Second, starting in Fall 2021, Livewire is focused on expanding access to more users, growing its catalog and features, and increasing user support. A Livewire Data Working Group (DWG) was established in 2021 to provide a forum for feedback and input from data owners and data users. A third strength of the project is a relatively comprehensive listing of milestones/quarterly progress measures.

The reviewer also listed some weaknesses for the project. One weakness is that the Livewire Data Platform project has an unusually long 6-yr period of performance. Another is that the metrics to truly gauge project success do not appear to have been comprehensively established.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer expressed that the technical accomplishments of the project team are very impressive. Building the platform to share data is impressive by itself, but the fact that Livewire has actively brought on contributors and grown its databases is an excellent indication of the ongoing success of the work.

Reviewer 2

The reviewer affirmed that technical progress is good. More automated ways of granting interested people access to the data, creating detailed metadata with considerations for scalability, streamlining and reducing manual processes, expanding quality metrics, and maintaining security are important. The research team may also consider how to improve the cost-effectiveness of the planned progress further, as it might be harder to justify the costs of incremental improvements in Livewire.

Reviewer 3

The reviewer commented that the technical accomplishments include user-facing site improvements, an updated design to enable embedded media and images on dataset pages, updated access and download permissions, metadata additions, data quality characterization, improved site security, and additional fleet datasets.

Reviewer 4

The reviewer cited several technical accomplishments for the project ,including: user-facing site improvements, an updated design to enable embedded media and images on project and dataset pages, updated access and download permissions, automated approval for .gov/.mil email accounts, detailed metadata additions, data quality characterization, site security, and improved site performance. The reviewer also listed several project weaknesses. The project appears behind schedule at only approximately 25% completion at more than halfway through the period of performance. In addition, There does not appear to be substantial progress on expanding the overall use of Livewire, nor establishing a clearly elucidated strategy to do so. Lastly, the overall addition of datasets seems to be relatively modest after more than 3 years into the project.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer expressed the testimonials from collaborators were very heartening to see. Based on this feedback, the team may want to consider what things are working to foster engagement in the future (if they are not doing this already). Additional items the team might consider are: 1.) for contributors, some categorization of the databases and a diagram of some kind indicating who is contributing to each of these categories of data (giving us a sense of the activity of lab contributors and whether there remains a dearth of data in certain categories) and, 2.) a corresponding figure of the users of data amongst each of these categories.

Reviewer 2

The reviewer stated that while there is a fair amount of collaboration across three project leads, it would be useful to show more clearly which tasks are addressed by each National Lab team member.

Reviewer 3

The reviewer noted the team has shown excellent coordination between Idaho National Laboratory (INL), NREL, Pacific Northwest National Laboratory (PNNL), as well as partnerships with DOE EEMS, Systems and Modeling for Accelerated Research in Transportation (SMART) and Technology Integration programs. Platform feature development is also motivated by various partners such as Carnegie Mellon University (CMU), LBNL, Virginia Tech, etc.

Reviewer 4

The reviewer stated the project development team of NREL (API Platform), PNNL (Data Portal), and INL (Quality and Metadata) is appropriate. The project appears to have been slow off the mark in identifying and expanding collaboration and coordination with other potential user entities. This may have been a leading reason Livewire has seen relatively limited use to date.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer observed that the project team has identified future considerations on Slide 20 (real-time or automated processing of new data, outreach activities). It might also be useful to consider explicit targeted outreach of data resources where the team identifies a need (e.g., for policy actors, equity considerations, etc.).

Reviewer 2

The reviewer found that the project team considerations for future work are good. As it is indeed difficult to source empirical real-world data applicable to new mobility technologies (CAVs), it is highly recommended to be creative in promoting Livewire aggressively in order to attract a plethora of new users with their own interesting data.

Reviewer 3

The reviewer determined that the proposed future development involving the addition of low-level metadata and quality analysis, self-service capabilities for data uploads, expanded in-platform user capabilities, and targeted outreach of users are all well-motivated.

Reviewer 4

The reviewer remarked that the Livewire Data Working Group should continue to be heavily leveraged to identify the means to further expand data provider and user participation. The project team's collaborations with the EEMS research community, VTO programs, and mobility researchers have and should continue. Moving forward, the Livewire team should consider out-of-the-box approaches and enhancements to further the platform's applicability, utility, and appeal to the broadest domain of users as possible. Additional work is needed to further clarify and substantiate metrics to conclusively determine (or not) Livewire's value.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer deemed the project aligns with VTO objectives.

Reviewer 2

The reviewer expressed that the relevance of this project to the overall VTO subprogram objectives is very clear as its goals are in development of a promising data sharing platform; the reviewer had no further comments!

Reviewer 3

The reviewer stated the project supports overall VTO subprogram objectives by providing a secure, scalable platform for data storage, characterization, and management.

Reviewer 4

The reviewer commented that Livewire is relevant. The establishment of a deep, expansive reservoir of transportation and mobility-related data that is secure, functional, easily accessible, and user friendly is beneficial to accelerate the cross-fertilization, research and development, and implementation of advanced transportation technologies and systems.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said the funding seems adequate, although there is some argument that the funding should scale up if the project begins to expand its current capabilities.

Reviewer 2

While this project seems to have sufficient resources, the reviewer suggested the researchers review the comments for Questions 4 and 6 for possible considerations on improvement.

Reviewer 3

The reviewer affirmed that the approved funding over multiple years is adequate for this effort.

Reviewer 4

The reviewer expressed that this project seems to be somewhat overfunded by DOE and there is no cost share.

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

Presenter

Dean Deter, ORNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

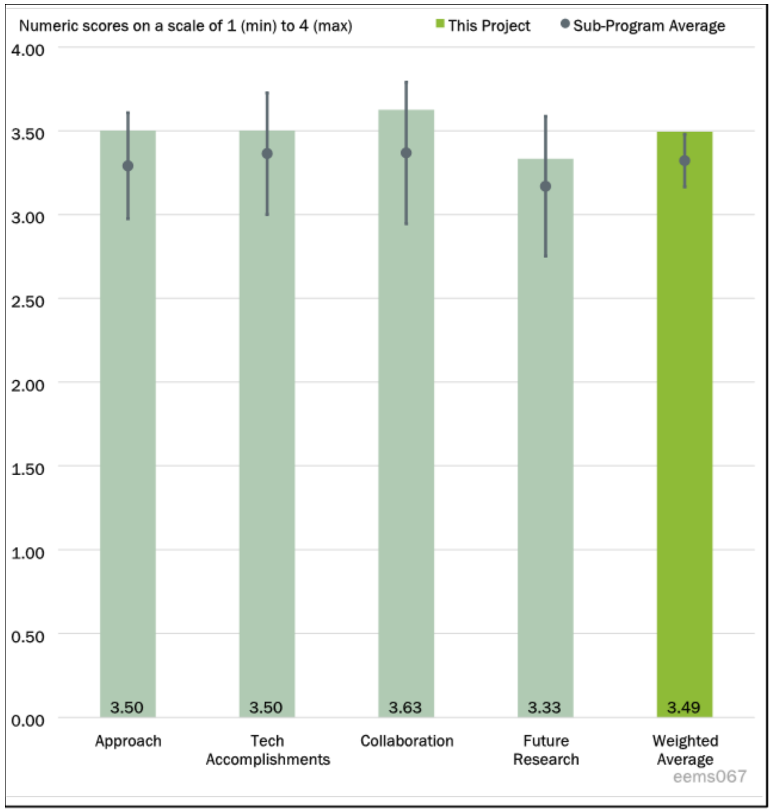

Figure 3-6 - Presentation Number: eems067 Presentation Title: Virtual and Physical Proving Ground (VPPG) for Development and Validation of Future Mobility Technologies Principal Investigator: Dean Deter, Oak Ridge National Laboratory

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer commented that this project is complete. The technical barriers were addressed and the project was well designed.

Reviewer 2

The reviewer determined that the team's approach to performing the stated work has been to create a virtual proving ground with communication modeling, development, and validation, allowing cross-platform data sharing and co-simulation.

Reviewer 3

The reviewer noted the project is well designed and the timeline is reasonable. The objective of developing a unified tool chain for CAV's is noble, but no small and trivial task. The team has partnered with great suppliers of hardware and software that will make the project goals obtainable. Taking the vehicle off the road and enabling CAV testing and validation of behavior is where industry is going and there are a number of OEM's and Tier 1 suppliers headed in the direction of creating these capabilities. Obviously, DOE's thrust is to make the tool chain more accessible and publicly available versus integrating multiple tools today that can be cost prohibitive.

Reviewer 4

The reviewer stated this is a timely project that aims at building an advanced modeling, simulation and analysis platform for CAV technologies/applications. Considering the impacts of the pandemic, the research team did an excellent job throughout this project. The project shows a proof-of-concept on the multi-resolution modeling for CAVs and XiL co-simulation (i.e., two testbeds).

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer expressed that the project made a lot of technical accomplishments on a topic that is very complex and requires the integration of a large number of disparate computers, software, and hardware systems to work together.

Reviewer 2

The reviewer remarked that the new Connected and Automated Vehicle Environment (CAVE) laboratory is fully functional and being used. A flexible interface for co-simulation has been developed and includes multi-ego vehicle set ups useable across distributed labs. The labs include hooks to real V2X and traffic control systems.

Reviewer 3

The reviewer noted the team's integration of dyno, vehicle, real and virtual hardware and simulation environment software is amazing to see and demonstrated on real maneuvers. One question is the capability of the wheel dynos to handle torque transients, varying road surface conditions, and the ability to turn the wheels to examine the more difficult lateral control of the vehicle. These last few features, handling large torque transients (accelerating from stop, panic stopping or passing), handling varying "mu" conditions, and planned path tracking, are key for validation of CAV behavior and control, not only for energy, but for safety.

Reviewer 4

The reviewer considered the technical accomplishments and progress of this project to be significant. The reviewer had several follow-on comments:

1.) It is not clear if the communication latency is significant or not for two test cells working together in Task 2. If it is, how did the research team address this issue?

2.) For the vehicle testbed on the dyno, how can the team model the positional errors in a more realistic manner? Most of the CAV applications require a certain degree of accuracy on the locations of equipped vehicles.

3.) How scalable is the platform? For example, if other institutions have similar setups (e.g., dyno and/or driving simulators), would it be feasible to hook up with the same platform and run the same simulation simultaneously?

4.) Did you consider sharing (onboard/roadside) sensor information over wireless communications in the platform?

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer stated the project had good collaboration across team members and was also required to coordinate with several other EEMS projects for applications to test.

Reviewer 2

The reviewer noted the team has shown good collaboration with the American Center for Mobility (ACM), IPG Automotive, dSPACE, and CARLA.

Reviewer

The reviewer said the team has the right collaborations in dSpace, CARLA, ACM and IPG Automotive for execution of the project. The team might consider reaching out to AVL Powertrain in North America, regarding the DRIVE CUBE hardware and Model.CONNECT software that gets at the essence of what this particular project is doing.

Reviewer 4

The reviewer intimated it is good to know that OEMs and universities are also involved. A more integrated driving force would be expected to move this research further along.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer commented the Virtual—Physical Proving Ground that was established under this project will be used in the near future to simulate/evaluate applications being developed under other current EEMS projects. Another potential future enhancement to the VPPG could be the integration of a more realistic wireless communications simulator.

Reviewer 2

The reviewer noted the project is complete.

Reviewer 3

The reviewer stated the slide and discussion around future research are a bit vague, but it appears the major thrust is to integrate with other funding opportunity announcements and current EEMS projects that are highly parallel. It was not totally clear what is left on the XiL development in the project. If the researchers could make clear what is left to develop with some detail on the XiL front, and how it contributes to energy consumption, that would be a nice addition.

Reviewer 4

The reviewer observed that the research team discussed a few barriers or challenges in the slides, which are all reasonable from the reviewer’s perspective. Also, some technical questions mentioned in Question 4 should be considered for future steps, as they might affect the fidelity and validity of the modeling platform.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer concluded that the project is very relevant to the EEMS program and established a virtual—physical testing environment that can be used to assess new application ideas.

Reviewer 2

The reviewer commented that the project supports the VTO subprogram objectives of setting up qualified virtual/hybrid laboratories to assess/evaluate/optimize technologies for electrified, connected and autonomous vehicles to reduce energy consumption.

Reviewer 3

The reviewer expressed that overall,the presentation and discussion was enjoyable. The thrust of the project is exactly what is going on at the OEM level to get rid of mule and development vehicles that require 1,000's of miles of testing and validation in unique environments. Having the ability to use unified tools without slow co-simulation to create the scenarios, and then test them at the vehicle level to acquire real response and performance, will be essential to fielding CAV technologies that improve safety and reduce energy consumption.

Reviewer 4

The reviewer agreed with the importance and relevance of an advanced CAV modeling and testing platform to enable EEMS research. However, it is recommended that the DOE effectively structure the research map on modeling/testing platform development to coordinate efforts and avoid too much overlap.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated the resources are sufficient and the project is complete.

Reviewer 2

The reviewer commented the approved budget for 2 years is appropriate.

Reviewer 3

The reviewer remarked that using multiple lab setups for vehicles in the loop with the developed simulation and environment tool chains is quite impressive and will be a significant enabler to complete the project and achieve the objectives. One thing to consider is correlation to real-world data. Is there a plan to essentially mimic and correlate results of the system to measured data of CAV's on the road? It is assumed this is likely, since ACM is a partner.

Reviewer 4

The reviewer deemed that resources for this project are sufficient, considering the involvement of various stakeholders, hardware, software, manpower and funding levels.

Presentation Number: eems082
Presentation Title: Validation of Connected and Automated Mobility System Modeling and Simulation
Principal Investigator: Dhiren Verma, American Center for Mobility

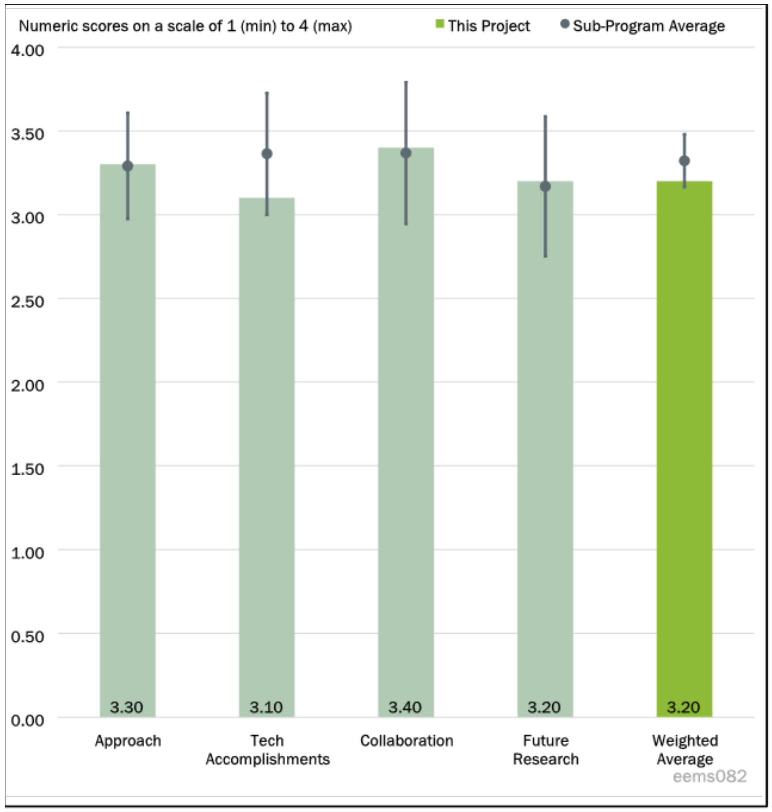

Figure 3-7 - Presentation Number: eems082 Presentation Title: Validation of Connected and Automated Mobility System Modeling and Simulation Principal Investigator: Dhiren Verma, American Center for Mobility

Presenter

Reuben Sarkar, American Center for Mobility

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer stated that the project has a clear approach and connection with other on-going activities funded through EERE. Proving simulation results in real-world testing is critical to advancing methods and algorithms to consumer use in the future.

Reviewer 2

The reviewer remarked that the project builds on previous/concurrent work and is a logical progression from algorithm to simulation to track. Involving ANL and ORNL is also helpful for efficient progress. The technical approach and timeline are reasonable.

Reviewer 3

The reviewer observed that the approach is excellent, using real algorithms and on-road test track experiments to improve algorithms that can then be incorporated into simulation tools.

Reviewer 4

The reviewer commented that the overall project approach appears well developed to meet the stated objectives, but the resulting transfer of insights and information is not obviously clear from the presentation. While quite a bit of infrastructure has been implemented for testing, subsequent updates and presentations will hopefully detail the insights and iterative transfer of information within the various laboratory projects that this project supports. Real-world data collection is a critical validation step for many DOE research technologies and this project can greatly aid in these efforts, but more details would be helpful to truly understand the benefits and specific items best done using track testing versus other simulation and/or emulation methods.

Reviewer 5

The reviewer said the main barriers defined in the project are real-world measurement of the energy impact of advanced controls enabled by CAVs as well as the modeling and simulation of large-scale transportation systems. One of the main concerns of the reviewer is the scale of the projects accomplished so far. The projects have been deployed in smaller testbeds and use only a few vehicles. This is not a real-world scenario nor is it a large-scale deployment that the barrier defines.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer stated that there is still work to do of course, but the project demonstrated success in iterative testing/development feedback loop working with both ANL/ORNL partners. It is clear that significant effort was undertaken to develop the testing capability.

Reviewer 2

The reviewer mentioned that project progress against the milestones is good. COVID and staffing challenges required a minor no-cost time extension for the project.

Reviewer 3

The reviewer commented that accomplishments to date include development of the testing environment and the completion of the speed harmonization case. One question is how are the results and the open source tools being communicated, distributed, etc. so that the entire community can benefit from this work? Another is whether the current outreach approach sufficient?

Reviewer 4

The reviewer expressed that although a significant amount of capability development has been achieved, it seems as if the analysis, execution, and transfer of insights is lagging behind the project schedule. From the presentation, it is not clear how the validation data and any real-world insights have made their way into any of the DOE control strategies and projects (one of the primary goals of the project). Given the project is expected to end in 2022, more insights into the specific controls and issues encountered in the field would be expected. The presentation primarily details the completeness of certain testing sections or capabilities, but the project team does not yet seem to have much analysis completed at the time of presentation. Also, it is not clear how the vehicle retrofits are ultimately being used in the overall process since single-physical vehicle testing appears to be the primary focus up to this point. Furthermore, it is not entirely clear what benefits have been identified from the field testing versus other forms of simulation and testing. For example, energy consumption data and model validation are discussed in the presentation, but this is something DOE funds from other projects; a clearer example outcome would be helpful to show how this outcome supports the overall project objective. It appears that a significant amount of time has been spent developing test plans and understanding test-to-test variation, but any insights gathered are not mentioned in the presentation. More clarity needs to be provided for the MiTe-μ micro-traffic simulation. DOE projects are already using Simulation of Urban Mobility (SUMO). VISSIM, and Amesim amongst other programs. It is unclear why an additional simulation was used; if needed, information should be shown to validate that this additional simulation is adequate to work for the validation and emulation tasks within these efforts. For the system performance discussion, it would be helpful to provide some insights into what an appropriate performance target should be for adequate vehicle performance. The given information does not give a strong indication if performance is simply adequate or dramatically better than needed for the validation needs of the different controls projects. Overall. it is clear that a lot of work has been done across a range of subcomponents, but it is not readily clear how all of the pieces fit together and supplement insight generation where a real-track environment is truly needed.

Reviewer 5

The reviewer commented that the team has configured a few test vehicles (EV, hybrid, and internal combustion engine [ICE]) and integrated algorithms developed at ORNL (speed harmonization and merging) and ANL (intersection eco-driving) into vehicles and infrastructure controls. Vehicles have been tested in controlled environments and results were compared. For each control algorithm, several scenarios were tested.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer stated significant coordination is required to execute projects of this scope. The team has clearly had success integrating work from each partner.

Reviewer 2

The reviewer noted that collaboration is good, especially by involving ORNL and ANL for specific applications. Michigan Technological University (MTU) does a nice job of leveraging prior and concurrent work that directly supports this project. ACM seems to struggle with staff continuity and that is a concern. It is important that sufficient technical expertise resides at ACM so that other research teams can quickly ramp-up to using the resulting tools.

Reviewer 3

The reviewer observed that collaboration among the team members appears to be excellent. It is unclear from the Annual Merit Review (AMR) what role California PATH has on the team. Can this be clarified?

Reviewer 4

The reviewer stated that the partnership between MTU and ACM seems to be established and running smoothly, but connections and feedback across the labs and their specific controls seems a bit less clear. While the lab efforts are separately funded, the collaboration to validate the controls and the specific insights gained for improved controls are not clearly highlighted in the presentation. Overall, the project seems well coordinated from a project management standpoint, but the exchange of information and iteration for improved controls and insights for DOE programs is not drawn out from the presentation materials. California PATH is also mentioned as a collaborator, but minimal information is provided as to what the collaboration component is for this partner.

Reviewer 5

The reviewer noted that there is great collaboration between American Center for Mobility, Michigan Technological University, ORNL, and ANL.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer stated that expanded testing plans to more cases is clearly defined and warranted given success of prior work implementing CAV strategies from ORNL/ANL.

Reviewer 2

The reviewer expressed that the proposed work is internally consistent with project objectives. The project is likely to achieve all objectives.

Reviewer 3

The reviewer mentioned that the future work being proposed may be unrealistic in scope. Five new use cases as well as evaluating highly automated vehicles, cybersecurity, vulnerable road users, weather, traffic, etc., is a lot to consider for the future work plan. A more focused list of future work would be more realistic. Also, it is highly recommended that the future work include outreach to automobile OEMs. The sooner that automobile OEMs get interested/involved in this type of research, the better in terms of near-term deployment

Reviewer 4

The reviewer commented that the near-term proposed work seems adequate to complete stated project objectives, but there is still quite a bit of testing, analysis, and feedback to support the overall project validation and strategy refinement goals of the project. Some additional future work items seem to be a bit more generic versus identifying specific additional supplementary efforts. The Proposed expanded scope seems reasonable, although some of the specific activities proposed do not necessarily align with current DOE controls development. Additionally, wireless power-transfer does not seem like a strong EEMS fit, although this would be possibly relevant for other DOE VTO programs. References to multiple vehicle physical testing is also not entirely clear as four vehicles were done for these efforts without explanation of what current testing is in/out of scope. Adverse weather conditions would be a welcome addition to these efforts as this is likely a major impediment for some of the prosed technologies being validated. Cyber-security analysis might also not yet be needed at the physical level as the hardware is developing so rapidly. Rather, a more detailed threat analysis would be a first step to ensure the correct priorities and issues are identified before investing in additional equipment or infrastructure.

Reviewer 5

The reviewer observed that the planned future work is to complete design and development of the experiments, validate results, and run experiments. This seems reasonable for the amount of time left on the project, but it does seem much of it is already done. Some of the future work on extending scope and integrating vulnerable road users are of interest, but it is not part of this project. It would have been good to include at least background traffic to the simulation and test the algorithms under heavy traffic as part of the planned future work for 2022.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer expressed that the project is very relevant and addresses required steps to bridge the gap from proof of concept to ultimate use in consumer vehicles.

Reviewer 2

The reviewer felt this work is very relevant by developing tools to bridge from desktop to track, allowing a reasonable number of experiments to demonstrate efficacy.

Reviewer 3

The reviewer stated that the project is very relevant to the EEMS program.

Reviewer 4

The reviewer noted that project goals and expected outcomes appear to be well aligned with EEMS goals, specifically, the continued development and real-world validation of DOE control strategies and technologies. While the stated intent to identify the levers leading to mobility fits within the overall EEMS scope, it would also be helpful to make clear the key points of validation and uncertainty to be assessed in these experiments (likely to be developed in collaboration with the DOE itself).

Reviewer 5

The reviewer mentioned that understanding the impact of CAVs in energy consumption of vehicles is a very relevant and timely topic.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer concluded that the scope of work is large, but the team clearly has the resources and facilities needed to complete the project.

Reviewer 2

The reviewer noted that resources are sufficient to execute the project. It is worth considering whether more resources would have provided more technical resource stability at ACM?

Reviewer 3

The reviewer remarked that the resources appear to be adequate to accomplish the project goals.

Reviewer 4

While somewhat on the higher-end, the reviewer commented that resources seem adequate for a large-scale vehicle development and infrastructure project. It is not entirely clear how much of the project was done prior to this project as some of the vehicles were highlighted as used in other projects, but this is not necessarily a negative reuse of resources. Overall, it seems a significant portion of the funds were used in capabilities development, which would be expected for this project's approach to developing and executing real-world validation. It would be helpful to understand how the overall capabilities mapped to specific implementation needs for the different projects and if there were any gaps in terms of capabilities, sensors, or needs that were still not addressed to fully emulate the developed DOE strategies.

Reviewer 5

The reviewer believed the team has sufficient resources to deliver the project.

Presentation Number: eems083
Presentation Title: CIRCLES: Congestion Impact Reduction via Connected and Automated Vehicle (CAV)-in-the-Loop Lagrangian Energy Smoothing
Principal Investigator: Alexandre Bayen, University of California at Berkeley

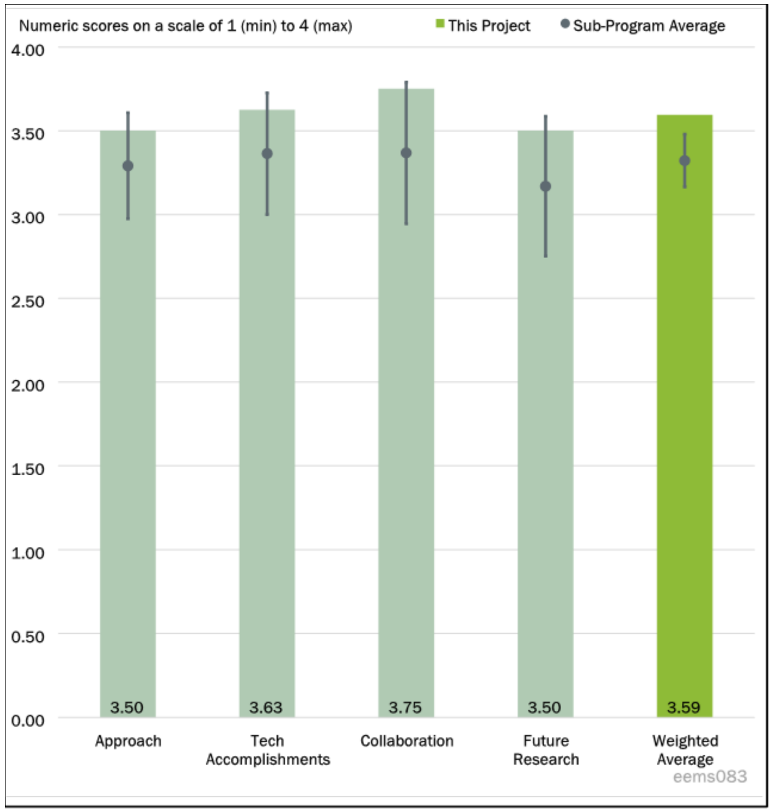

Figure 3-8 - Presentation Number: eems083 Presentation Title: CIRCLES: Congestion Impact Reduction via Connected and Automated Vehicle (CAV)-in-the-Loop Lagrangian Energy Smoothing Principal Investigator: Alexandre Bayen, University of California at Berkeley

Presenter

Alexandre Bayen, University of California at Berkeley

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer commented that all of the 2022 milestones are on-track (in spite of, for example, supply chain challenges). The simulation engine is complete, elements of the project are being fine-tuned, and the project is actively working on testbed development, field tests, and hardware implementation. The work appears to be on-schedule.

Reviewer 2

The reviewer pointed out that both of the barriers identified in Slide 2 are well addressed throughout the presentation. The evolution of technologies that has enabled connectivity and automation is clearly what has allowed for this project to happen, and the project team has nicely demonstrated the use of these technologies throughout the presentation. The accuracy of measuring energy impacts of the CAVs within the project is well demonstrated in the testing of the vehicle controllers. However, details of the measurement and calculation of energy consumption of the vehicles affected by the controllers was not entirely clear. This is a critical component of the successful evaluation of the project, as these measurements will determine the energy savings from the controllers.

Reviewer 3

The reviewer mentioned that the approach is very well thought out. The use of the video-based trajectories of all vehicles traveling along the section of the highway is a major "game changer" and is the key to determining if 100 vehicles in the traffic stream can really make a difference.

Reviewer 4

The reviewer stated that the project design is comprehensive, with keen awareness and consideration of the interactions between multiple, complex steps. The timeline for the remining work, which depends at least partly on timely completion and shakedown of the I-24 MOTION (MObility Technology Interstate Observation Network) test bed, is tight and may need to be extended.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer remarked that project progress is advancing, clearly outlined in terms of each respective goal (developing and evaluating vehicle controller candidates, scaling to 100 vehicles and 100 drivers, designing and constructing the I-24 MOTION testbed, and executing large-scale field-testing, respectively). Work appears to be largely on-track and next steps have been provided.

Reviewer 2

The reviewer noted that the technical accomplishments are impressive, and the progression from simulation models to deployment of vehicle controllers is one step closer to real-world application. The project team seems cognizant of the implications of their experiment and are taking appropriate measures of safety while deploying the project.

Reviewer 3

The reviewer intimated that it is impressive that the project has remained essentially on schedule during the supply chain delays.

Reviewer 4

The reviewer observed that this ambitious project appears to be on track to the extent possible, and project leaders seem to have successfully dealt with challenges and barriers to date. These include critical supply chain issues for I-24 MOTION test bed equipment, as well as institutional review board and safety considerations.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer felt that the project pulls in a variety of partners (including several universities, industry, and government), with each entity contributing in a distinct way to the work.

Reviewer 2

The reviewer affirmed that coordination and specific contributions of each partner is very well described on Slide 13, and has no comments on the collaborative aspects of this project.

Reviewer 3

The reviewer commented that the team is well coordinated with university partners, the Tennessee DOT, and two automobile OEMs (Toyota and Nissan).

Reviewer 4

The reviewer said this project appears to have attained its very high level of success to date through excellent coordination between multiple partners with clearly defined roles. This coordination is well done.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer commented that the project presentation clearly outlines proposed future research. Given past performance and the ability to leverage lessons learned from the work thus far, the future work is positioned to potentially achieve its targets. (Although there may be some challenges that pop up, for example related to the scale up to 100 CAVs, experience and considerations thus far may inform subsequent decision-making to overcome hurdles.)

Reviewer 2

The reviewer expressed that the technical aspects of the future research described in Slide 15 are logical extensions of the current project. It is suggested that further consideration be given to the first point made on Slide 14 and how behavioral elements may affect the potential energy savings of the experiment. Even if the project team is unable to mitigate "aggressive" behaviors (or non-efficient driving behaviors), quantification of these aspects of the project would be very valuable in better predicting the real-world implications of the controllers.

Reviewer 3

The reviewer stated the proposed future research has some challenges that were acknowledged by the project team. It may be difficult to fully understand all the nuances of the 100 car experiment until it is actually attempted with the 100 cars. The team will need to stay flexible and have "back up" plans for many aspects of the testing, including parking locations, spacing of vehicles, vehicle lane assignments, etc. The extent to which the team can develop "back up" plans may determine successful completion of the 100 car testing.

Reviewer 4

The reviewer said the proposed future research is spot on toward the end goal of evaluating the system energy implications of the 100 CAV fleet, although timing is tight.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer stated that this project is working to develop and demonstrate AI and control algorithms that smooth traffic flow and provide at least 10% energy savings. As increasing mobility energy productivity and building "an affordable, efficient, safe, and accessible transportation future" is the mission/vision of EEMS, this work supports DOE objectives.

Reviewer 2

The reviewer confirmed that VTO objectives are being met from this project.

Reviewer 3

The reviewer indicated the research is very relevant to understand if low levels of equipped "energy maximizing" vehicles in the traffic stream can actually make a difference in the behavior of the total traffic flow along a section of highway.

Reviewer 4

The reviewer observed that this project clearly supports the VTO EEMS strategic goals. Identifying the role of relatively low rates of CAV penetration on reducing system-wide energy supports the goal of "identifying the most important levers to improve the energy productivity of future integrated mobility systems." Development and testing of multiple control algorithms and the I-24 MOTION test bed supports the goal of developing "innovative technologies that enable energy efficient future mobility systems."

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated that although additional resources could potentially help support additional testing and data collection, given that the project is 80% complete and work is on-track, the resources available seem to be generally sufficient.

Reviewer 2

The reviewer concluded that the resources of the project seem adequate.

Reviewer 3

The reviewer commented that the project appears to have adequate resources to complete the work. However, if the 100 vehicle experiment needs to be continually "tweaked", this could result in a request for additional funding.

Reviewer 4

The reviewer mentioned that the assembled team and its associated commitment towards goals appear to be excellent. The time needed to achieve the critical milestones 3.3 and 3.4 is challenging, and may need to extend beyond FY 22. If additional time is needed, the reviewer stated support for granting it, in order to realize the full potential of the work to date.

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

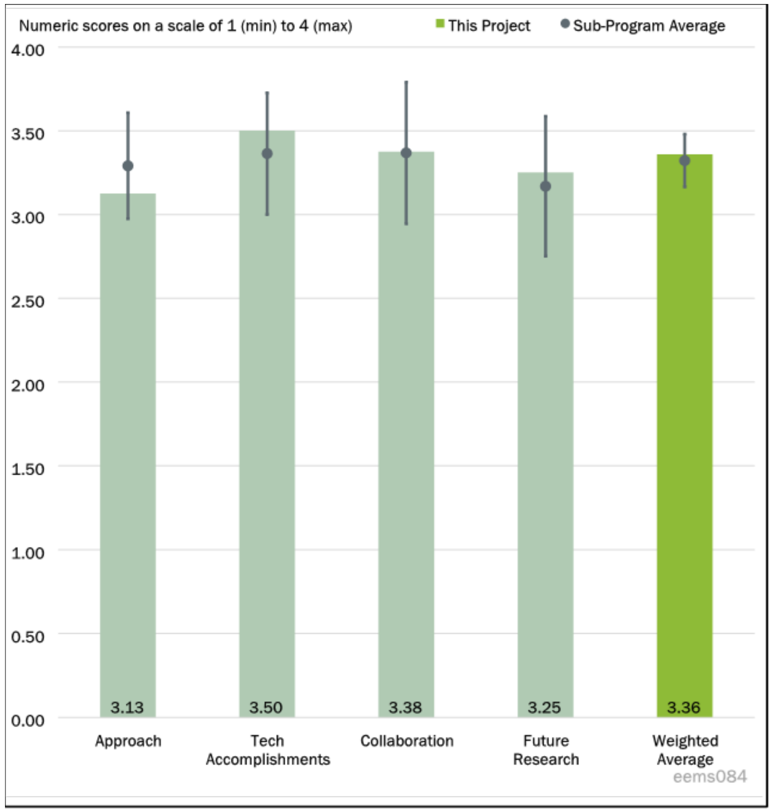

Figure 3-9 - Presentation Number: eems084 Presentation Title: Energy-Efficient Maneuvering of Connected and Automated Vehicles (CAVs) with Situational Awareness at Intersections Principal Investigator: Sankar Rengarajan, Southwest Research Institute

Presenter

Sankar Rengarajan, Southwest Research Institute

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer commented that project milestones are well laid out and appear to have either all been completed on schedule or are proceeding on-time. The work seems to be well targeted and considers a variety of vehicle types, exploring the benefits of CAV technologies across different powertrain types and automation levels. The research seems well designed overall, although the team might consider the question of variability across different urban corridors.

Reviewer 2

The reviewer remarked that generally the slides indicated targets rather than barriers (Slide 2); however, some of these targets were not addressed in the presentation. While a framework had been developed to estimate the energy benefits, there was no mention of emissions and cost benefits in the project slides. Likewise, target outcome 2 indicates that the simulation would be “quantified and validated with real-world data”; while this is true in that data was garnered from a dynamometer, ultimately the presenter indicated that this should happen with a vehicle in real-world conditions.

Reviewer 3

The reviewer mentioned the approach to use simulation is good because this is the only method that can really try to quantify all various combinations of vehicle type, market penetration, infrastructure equipment, etc. One limitation is that for the corridor simulation, the results may be somewhat dependent on the specific Columbus, Ohio corridor that is being modeled. Using dynamometer and test track testing is also a key component of the approach.

Reviewer 4

The reviewer stated that the project is a helpful investigation into the effectiveness of CAV technologies on system-level energy implications, with a useful mix of vehicle powertrain and automation levels. The project provides solid technical work overall in developing and testing software-in-the-loop. Some weaknesses include representativeness and, therefore, scalability/broader applicability, including the intersection stack and associated communication protocols, and the driving corridor. This is a useful initial project; its broader applicability seems to call for additional efforts, including real world pilots in a more diverse array of applications, before it is ready for more serious consideration of tech-to-market.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer commented that the presentation provides a robust breakdown of results to date and highlights the implications of these findings effectively. The team appears to be solidly on schedule and working in line with milestones and laid out project plans.

Reviewer 2

The reviewer said that technical progress has been well demonstrated. The main deviation from the project plan relates to cost and emissions. These seem to be rather smaller components of the overall research efforts, as they can be post-process results from the bulk of the work. Otherwise, the project team has made substantial progress and demonstrated a very neat sets of results, although more work remains to be done for real-world validation and deployment in real cities.

Reviewer 3

The reviewer felt the project team has made significant progress in conducting the simulations and in verifying simulation results with dynamometer testing. The team also seems to be making progress on the tech-to-market component through engagement with the City of Chattanooga.

Reviewer 4

The reviewer deemed the project a valuable demonstration of system-wide energy reductions under various simulated conditions, including relevance of smart vehicle penetration and importance of vehicle-to-vehicle (V2V) versus vehicle-to-infrastructure (V2I). Additional exploration of the implications of V2I versus V2V will be important future work to better understand the key drivers of their success (or lack thereof) under an increasingly wide array of conditions.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer stated that the project combines partners with different strengths and roles in the industry. The role of each partner was laid out. Given the results thus far, the partnership seems to be operating fine, although additional information about the partnership would also be of interest. It is great that Alamo Area Clean Cities Coalition is helping to facilitate public sector coordination and outreach.

Reviewer 2

The reviewer observed that collaboration and coordination with partners are nicely documented on Slide 19. The roles are clear, and there are no further suggestions for improving collaboration.

Reviewer 3

The reviewer deemed project team collaboration and coordination among team members to be very good.

Reviewer 4

The reviewer said project coordination appears to be fine. A summary of the results of the tech-to-market efforts, including outcomes of discussion with public entities and techno-economic analysis, would be useful.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer observed that the project outlines plans for future work, including subsequent testing and demonstration. The team is likely to achieve its target, although the researchers also lay out opportunities to expand on work beyond the project time frame (for instance, there could be additional collaboration with other cities, OEMs, etc.).

Reviewer 2

The reviewer stated the team has a clear vision of proposed future research, and the test track technology demonstration and pilot testing in a true urban corridor are logical extensions of the current work. Although there are certainly many challenges with implementation, carrying out the team's vision for upcoming research would ultimately lead to outcomes supporting the initial goals of the project. It is also suggested the team try and consider the generalizability of the findings across different networks. This means the team should attempt to characterize the factors (both static and dynamic) of the road networks and traffic conditions that could then be operationalized to understand the potential energy savings being measured in this project.

Reviewer 3

The reviewer commented that the future research component includes the test track demonstration. However, it is a little unclear as to how the test track results will be used, other than a feasibility test of implementation of some of the simulated technologies. For example, will the test track results be used to improve the simulation models?

Reviewer 4

The reviewer expressed the proposed future research includes reasonable next steps, although they are somewhat undefined. The research would benefit from elaboration on the expected outcomes and goals to accomplish these steps, including clarification on specific tasks and timeframes.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer remarked this project is working to quantify and understand the benefits of CAV technologies on an urban corridor and to understand the impact of intelligent infrastructure platforms from an energy efficiency perspective. This can potentially help to advance informed deployment/application of CAV technology to support more energy-efficient travel in the future. As increasing mobility energy productivity and building “an affordable, efficient, safe, and accessible transportation future” are part of the mission/vision of EEMS, this work supports DOE objectives.

Reviewer 2

The reviewer confirmed this project is aligned with VTO objectives.

Reviewer 3

The reviewer stated this research is relevant to EEMS and addresses improved operations of vehicles on equipped traffic corridors.

Reviewer 4

The reviewer commented that the demonstration of simulated system-wide energy reductions resulting from CAV technologies, including the relevance of CAV penetration and vehicle-to-everything (V2X) approaches, works towards achieving VTO EEMS strategic goal #1, the identification of the “most important levers to improve energy productivity of future integrated mobility systems.”.

*Question 6: **Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?***

Reviewer 1

The reviewer indicated that while more time and resources could help to further gather data and better capture and understand associated real-world complexity (for instance across different road/driver environments), the resources generally seem sufficient to work towards the stated project goals.

Reviewer 2

The reviewer concluded that this project seems to be adequately funded.

Reviewer 3

The reviewer observed that the project appears to have sufficient resources to achieve the remaining milestones. However, getting the test track demonstration to work does have some challenges as outlined by the project team, but the team has also identified mitigation solutions for these challenges.

Reviewer 4

The reviewer said resources seem sufficient to achieve the goals outlined for budget period 3.

Presentation Number: eems089
Presentation Title: Energy Efficient Connected and Automated Vehicles (CAVs), Workflow Development and Deployment
Principal Investigator: Dominik Karbowski, Argonne National Laboratory

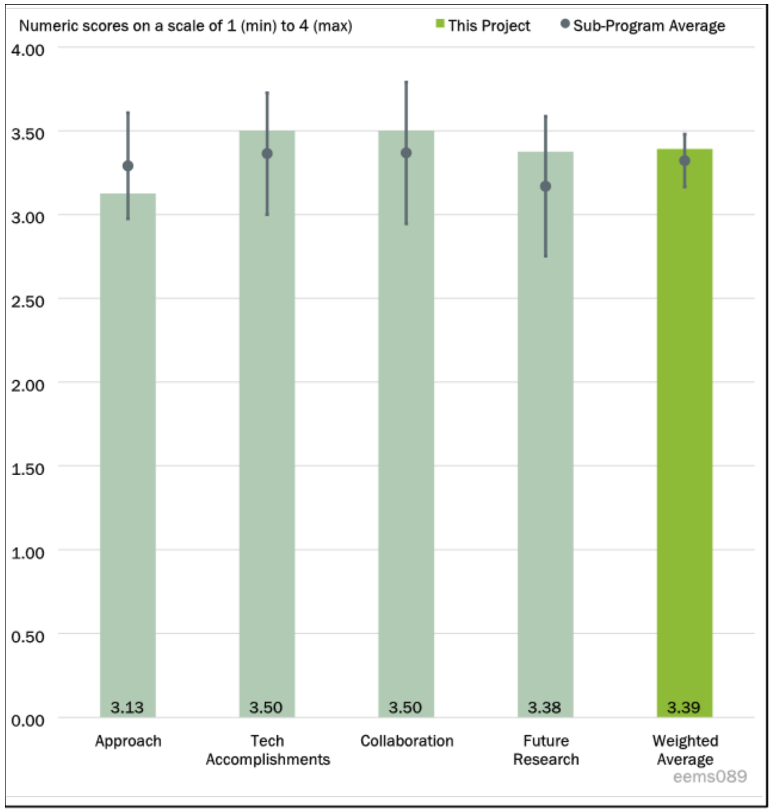

Figure 3-10 - Presentation Number: eems089 Presentation Title: Energy Efficient Connected and Automated Vehicles (CAVs), Workflow Development and Deployment Principal Investigator: Dominik Karbowski, Argonne National Laboratory

Presenter

Dominik Karbowski, ANL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer stated the team has clear barriers but the approach slides and discussion were a bit unclear the specific role this project plays. The interconnection of the many related projects was clearly conveyed, but with so much discussion of the rest, the project deliverables are unclear. Especially for those not intimately familiar with the prior work, the context of this presentation was very hard to digest.

Reviewer 2

The reviewer observed the project does a great job of covering all of the potential means of vehicle-to-x interactions and processes to model these interactions in a way that produces meaningful data.

Reviewer 3

The reviewer commented that the real vehicle demonstration of energy consumption has historically been quite difficult, particularly if the project focus is on powertrain energy reduction and the demonstration requires taking control of or over-riding OEM controls. Generally, this is not possible and even if partnered with an OEM, objections to allowing this control are made in favor of safety or torque security. However, with the dynamometer and coupling with virtual in the loop approaches of this project, these barriers can be overcome. The approach presented and accomplishments reported support this point.

Reviewer 4

The reviewer remarketed that development of advanced tools and platforms (e.g., XiL) to evaluate energy impacts of CAVs has significant importance. In recent years, various institutions have been developing their own tools or platforms for similar purposes. With the leverage of DOE national laboratory resources, the research team should be able to develop a comprehensive product. Based on the presentation, the team is moving forward to the right direction.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer cited specifics of the Sensor/V2X development are not clear as to which parts are newly developed or just integrated. The density of slides makes this hard to absorb even in post presentation review, let alone live. The workflows/software sections are reasonably clear though discussion was too deep at times for a review presentation.

Reviewer 2

The reviewer said that considering the number of moving parts (organizations, collaborations across organizations) in this project, progress has been outstanding, The project is delivering the results anticipated in the project plan on time.

Reviewer 3

The reviewer found that the team has made significant progress and accomplishments in the area of lateral dynamics and human driver models that seem to be a deficiency in most other current or previous projects. The workflow integration of traffic analysis and modeling with the XiL is key to demonstrating representative energy consumption characteristics and behaviors. The coupling of the tools to vehicle or vehicles on the test track is great for developing various scenarios that represent real world behavior. A number of other EEMS projects and automotive consultancy companies are on parallel paths. The enhanced features in Roadrunner as an outcome of the project to date are spot on and look fantastic. When will these features be readily available for field distribution?

Reviewer 4

The reviewer noted the technical accomplishments and progress make sense and the entire project follows the plan very well. The reviewer also had several questions and comments as follows:

1.) To enable the mixed reality test environment, it might require high-fidelity simulation network and scenario setup. How does the research team guarantee the simulated environment to be as realistic as possible to facilitate the integration with a real testbed?

2.) Will weather impacts be considered in the future development effort?

3.) How will the realistic interaction behaviors be modelled by the proposed platform and what kind of real-world data will be used to validate these modeling efforts?

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer thought the large team seemed effectively managed. The roles are defined throughout the presentation which was appreciated.

Reviewer 2

The reviewer remarked that the project exhibited great teamwork between academic institutions, national labs and at least one OEM. Since a lot of the work is aimed at developing techniques to coordinate movements among a mixed group of vehicles, the effectiveness would be greatly enhanced if there were a standard developed around what vehicles do with the V2X information presented. If vehicles do not react in the same predictable manner, it would seem the control effectiveness is diminished. Is there such an activity planned? Or is that considered out-of-scope?

Reviewer 3

The reviewer said that integration with Hyundai to get data for improved human driver model and traffic behavior is amazing. Leveraging the telematic systems from OEMs to develop large datasets for learning and model development is a rapidly expanding element being found in a number of DOE EEMS VTO projects. The team should be very proud of this work and the level of support from the OEM. The collaborations with other entities seem spot on and appropriate for accomplishing other facets of the project.

Reviewer 4

The reviewer commented it is good to see the collaboration between ANL and other stakeholders, e.g., universities, and automakers. It would be great if there is a closer coordination between DOE national laboratories, or between DOE and USDOT.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer observed the future work to clear and appropriate given current progress. It seems likely that the team will achieve its targets.

Reviewer 2

The reviewer said project next steps are a logical extension/expansion of the work done to date.

Reviewer 3

The reviewer stated the deployment of tools and workflows will be interesting to note on how they are used and leveraged for CAV development. The AI-based prediction and calibration methods, in general, seem to be a converging approach for a number of DOE EEMS projects. It will be good to see the team utilizing collaborative partners in developing these components of the project.

Reviewer 4

The reviewer expressed the future research mentioned by the team makes sense. Besides, some of the questions in Question 4 list may be considered as future steps.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said integrating tools is definitely relevant and a required step if techniques are to be adopted more broadly.

Reviewer 2

The reviewer confirmed the project is highly relevant to EEMS advancement of CAV technology and to working out the associated problems in a publicly accessible forum.

Reviewer 3

The reviewer concluded that this project ties into other EEMS projects very nicely, i.e., EEMS 067, EEMS 089, etc. The project is also highly relevant in decreasing the development time of CAV technologies with the specific focus of reducing energy consumption, and in validating that the technologies fielded do in fact reduce energy consumption under a broad range of driving situations.

Reviewer 4

The reviewer fully agreed with the importance and relevance of an advanced CAV modeling and testing platform to enable EEMS research, or more specifically, CAV energy related research.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer felt the resources are appropriate and well-integrated.

Reviewer 2

The reviewer commented the project is well funded and is progressing nicely.

Reviewer 3

The reviewer stated the team does appear to be sufficiently resourced and partnered/collaborating with external entities that enable execution of the project in the proposed time frame.

Reviewer 4

The reviewer affirmed that the resources of the project are sufficient. Leveraging the resources from DOE national laboratories is considered to be a plus for this project.

Presentation Number: eems090
Presentation Title: Applying Artificial Intelligence (AI) Based Signal Coordination and Controls for Optimized Mobility for the Nimitz Highway
Principal Investigator: Hong Wang, Oak Ridge National Laboratory

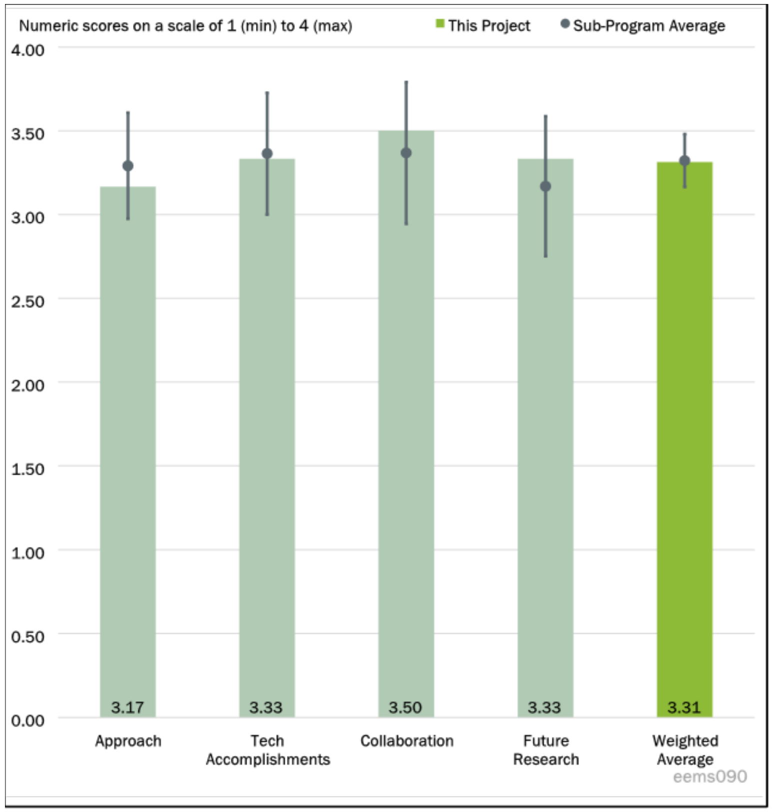

Figure 3-11 - Presentation Number: eems090 Presentation Title: Applying Artificial Intelligence (AI) Based Signal Coordination and Controls for Optimized Mobility for the Nimitz Highway Principal Investigator: Hong Wang, Oak Ridge National Laboratory

Presenter

Hong Wang, ORNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer wondered whether the only data available long-term would be from the signal controllers installed, or if additional inputs would be available to feed the hybrid neural network? Understanding travelers' choices (e.g., taking alternate routes depending on traffic volume) would be important. Performing a before/after analysis would allow for a better comparison of the proposed approach.

Reviewer 2

The reviewer commented that overall, the project has a strong approach. Leveraging existing infrastructure as well as a focus on real-world benefits fit well with the overall approach and needs of the EEMS program. The focus on 24/7 real-world implementation of AI algorithms is much appreciated as a direct and real-world evaluation of promising AI methods. The project leverages recently installed traffic control technologies and facilities from Hawaii-Department of Transportation (HDOT), which is a strong starting point for high-value DOE investment (i.e., focusing on algorithm development versus infrastructure building). Year 2 focus on real-time implementation should provide a strong validation for the improvements shown in the simulation portion of this work. The combined goals of energy reduction and travel delay reduction are helpful to ensure a balanced application of the developed algorithms towards real-world improvements.

Reviewer 3

The reviewer stated the research team leverages the real-world traffic data, modern control theory, and machine learning (ML) technique to optimize the traffic signal operation along a major corridor in Hawaii. The approach makes sense. Due to the complexity of the problem, the application of ML techniques is promising from a practical point of view. To ensure the validity of the approach, the richness and fidelity of the real-world data as well as operational constraints (e.g., minimum green/maximum green) need to be guaranteed.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer observed the project seems to be on time based on the suggested timeline. However, the data aspects are not clearly integrated. Similar to the comment above, would other data be needed or just the controller will suffice? I know the project is trying to minimize data needs, but there are other aspects that might be of interest.

Reviewer 2

The reviewer commented that Year 1 efforts have resulted in a strong set of preliminary results and publications, including an IARIA best paper award and keynote speech. So far, project progress and accomplishments appear to be in line with the goals of developing algorithms and creating/validating the simulation environment under which the algorithms will be developed. Simulated results show strong progress towards travel time and energy saving goals. Since the project uses existing infrastructure, it is expected that the transition to real-world testing will be relatively smooth.

Reviewer 3

The reviewer felt the research team made a good number of technical accomplishments, including the earning of the Best Paper Award from a conference. The reviewer also offered a few comments regarding the technical details of the research:

1.) The model seems to be updated every two cycles, which might be a trade-off considering computational time and optimality. It would be great if cycle length is considered as a decision variable, although it might need to be consistent across the entire corridor.

2.) More detailed traffic information (e.g., lane-level rather than approach-wise queue length) is suggested to be available for the AI-enabled traffic signal optimization.

3.) It is assumed that there are quite a lot of pedestrians/bicyclists (e.g., tourists) crossing the intersections at the study site. If so, does the signal control need to take into account the impacts of these modes.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer commented that the work done to coordinate and navigate the implementation of this program in an island is impressive.

Reviewer 2

The reviewer stated that the project team has a strong mix of backgrounds and expertise. Working with Econolite provides strong and direct support for the implementation and learning of the developed techniques into real-world traffic systems. Working with HDOT is also a strong positive to this project as a primary stakeholder for these techniques and will ultimately be responsible for integrating the project learning and insights.

Reviewer 3

The reviewer observed research partners include HDOT, Econolite, and academia. These partners should provide good coverage of different perspectives on the traffic signal operation. It would be great to learn more feedback from the end user, i.e., HDOT, or by conducting a survey of road users (e.g., local residents).

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer remarked the future research topics are as expected for this type of work. It would be good to compare the resulting improvements to an island versus to different metropolitan or rural areas.

Reviewer 2

The reviewer deemed the future work is in line with the expected project goals and outcomes. The transition to real-world implementation and data collection seems well-established and should be relatively smooth. The project team seems capable of achieving future milestones and the implementation results from the project applied in the real-world should be exciting to see. It would be helpful to highlight the degree to which the obtained results could be applicable to other systems—both in terms of transferring the learning algorithms to other traffic systems as well as any high-level abstractions for the "rules" created by the neural networks utilizing emerging developments in explainable ML.

Reviewer 3

The reviewer found the proposed future plan to make sense. Besides the focus on improving signal control algorithms (e.g., applying different ML techniques),here are two other major areas that may require attentions: 1.) It would be important to better predict the network-wise traffic states by taking advantage of real-world data and applying advanced ML technique; and 2.) The multi-modal interaction at intersections or along the corridor should be treated with care.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer intimated that assisting non-continental US states and territories should be a priority for VTO EEMS due to the energy crisis for several of these regions. Similar programs could be applied and compared to other US territories.

Reviewer 2

The reviewer believed the project is very much in line with EEMS goals both in overall project intent and balance between travel time and energy reduction as well as in a focus on real world implementation with a mix of strong and highly relevant project partners.

Reviewer 3

The reviewer commented the project is focused on traffic signal optimization for improving mobility of the whole transportation system. There are also efforts on accessing energy impacts or even plans on signal optimization for energy consumption. It aligns with the VTO subprogram (e.g., EEMS) scope and support the corresponding objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer remarked that while performing research outside of the continental US is expensive, the project resources are sufficient. However, depending on what is needed for more implementations. The project might need additional funds.

Reviewer 2

The reviewer found resources to be adequate. Project focus on leveraging recent HDOT investments also offers a strong value-proposition for DOE.

Reviewer 3

The reviewer indicated that the support or collaboration with Hawaii DOT, Econolite, and University of Hawaii should provide sufficient resources for the project. Considering the percentage (60%) of completion and the project timeline (end in January 2023), the research team may need to increase efforts to ensure project completion in a timely manner.

Presentation Number: eems092
Presentation Title: Behavior, Energy, Autonomy, Mobility (BEAM) CORE
Principal Investigator: Anna Spurlock, Lawrence Berkeley National Laboratory

Presenter

Anna Spurlock, LBNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

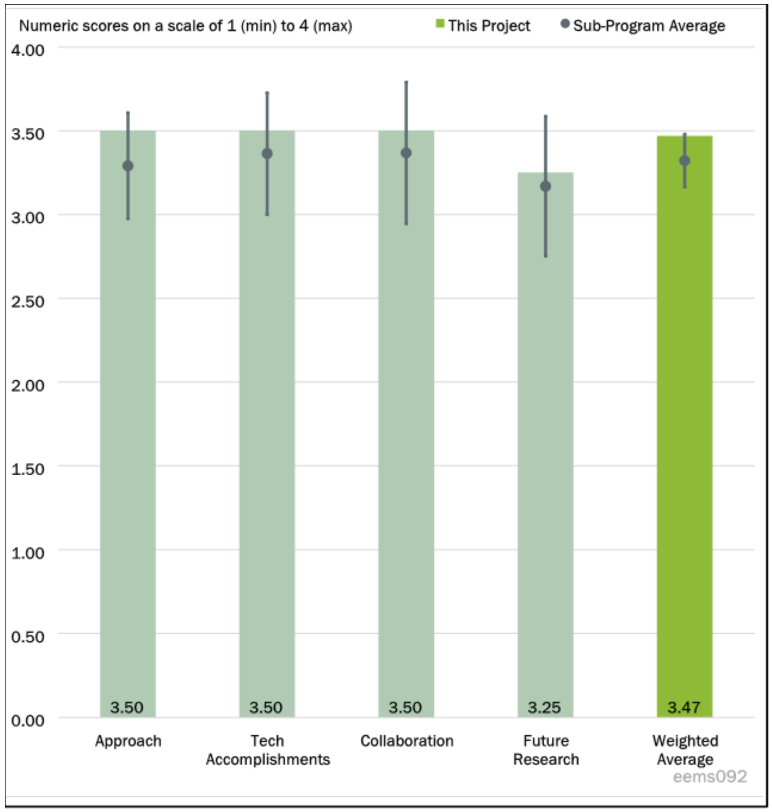

Figure 3-12 - Presentation Number: eems092 Presentation Title: Behavior, Energy, Autonomy, Mobility (BEAM) CORE Principal Investigator: Anna Spurlock, Lawrence Berkeley National Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer commented that it is commendable that the project team made early and extensive efforts to solicit inputs from key stakeholders to help inform the design and development of the modeling framework. The open source nature of BEAM CORE is important for model transparency, dissemination, and evolution. The fact that BEAM builds upon MATSim, which is also open source, demonstrates this importance. The modeling framework of BEAM CORE is comprehensive, and represents the interactions among various components well. The incorporation of DEMOS to model population evolution is novel. The ability to model detailed socioeconomic characteristics (including equity-related ones such as race) of individual agents (persons) equips the modeling framework well for analyses of equity impacts of future mobility technologies and policies. Also, ACT looks to be a useful tool for sharing modeling results with stakeholders. Lastly, the modularity of the modeling framework where individual models can be used independently will add value to the final product.

Reviewer 2

The reviewer indicated this is a very complex project, by design. “All models are wrong. Some are useful.” The most important aspect of this complex model project is that it is open-source. That addresses the largest technical barrier. A black box tool is easy to use, but difficult to verify correctness. The open-source nature makes this tool verifiable. Other researchers will question how it functions and potentially modify it to suit their needs. If the tool gains sufficient traction with researchers, it could indeed provide valued inputs to policy makers and planners. Computational requirements are a challenge, but more tools are coming (e.g. quantum computing).

Reviewer 3

The reviewer stated technical barriers presented in Slide 3 are posed as more of generalized research questions, but it would be helpful if specific barriers to the modeling work were identified. These barriers could then act as a focal point in explicitly providing the audience with information on what efforts were taken in the modeling approach to overcome them.

Reviewer 4

The reviewer observed that the project has a well-defined approach to consider household evolution and vehicle ownership dynamics, demographics, vehicle transition and technology adoption, and freight capabilities. By considering new technologies, evolution in each household, demographics, and technology adoption, a fairly clear picture can be achieved that can be used for planning and analyzing impacts of different options.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer remarked the project seems to be on track with reasonable progress made to date. The number of technical accomplishments is impressive, but not surprising given the size of the project and the expertise of the project team. The performance enhancement of the model framework is focused on the right areas (faster runtime, tighter integration with end-to-end automation, more accurate representation of phenomena and behaviors, etc.). The incorporation of freight capabilities is a major undertaking, but is also important for capturing the interactions between passenger and freight movement in transportation systems. The progress made up to this point is promising.

Reviewer 2

The reviewer said that based on the milestones and checkmarks, the project is on-track.

Reviewer 3

The reviewer expressed the presentation clearly demonstrated progress on the modeling front and expanded capabilities of the BEAM CORE system. Slides 35 and 36 were excellent to see, providing a view beyond technical modeling aspects to an explicit demonstration of application and outreach activities. It might be beneficial to follow up with some of the stakeholders to gauge whether workshops and meetings led to any real-world impacts. The team also explicitly calls out efforts to consider equity outcomes in the modeling. In the same vein, the team should consider engagement with specific stakeholders to push for equity impacts of their research as well.

Reviewer 4

The reviewer noted the team has accomplished good models. Validation of some of the earlier models are provided which are shown to be promising. However, more validation and in-depth planning for such validation are needed.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer stated that coordinating a multi-partner team in a highly complex project is always challenging, but the progress and accomplishments presented indicate well-coordinated efforts. The integration of multiple models in the framework with automatic handoff of model inputs/outputs can only happen with good collaboration among the partners within the project team. The number of external partners from universities and industry is limited. There may be additional datasets or modeling expertise that can be brought in to further enhance BEAM CORE.

Reviewer 2

The reviewer said there are many partners with a large budget. The project appears to be well coordinated.

Reviewer 3

The reviewer noted that collaborations are very nicely documented on Slide 40; no further suggestions are offered as it seems that the team id working cohesively on the modeling.

Reviewer 4

The reviewer confirmed this is a strong team of collaborators from multiple labs.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer commented the proposed future research is mapped out very well, and represents reasonable milestones toward achieving the project goals.

Reviewer 2

The reviewer stated future milestones are internally consistent with overall project objectives. The project appears to be on track.

Reviewer 3

The reviewer noted the project team has nicely identified challenges and proposed future research to continue the project on Slides 41-43. One primary concern is whether some of the challenges of the modeling effort can be overcome. BEAM CORE is already a fairly complex modeling system, and it is unclear whether computational performance can be substantially improved to the point where the model is readily available and accessible to interested stakeholders. Additionally, the model is “designed to be deployable to most regions...with publicly available data”; are the parameters and inputs needed to run the model readily available to allow BEAM CORE to cover the rest of the US? Adding additional regional coverage is a fairly large effort to include, and if so, the team should be more explicit about this. Lastly, it is suggested that a greater emphasis be placed on Task 4 (application and outreach) specifically with regards to model/output accessibility. In what ways can the model (or its outputs) be made more readily available to interested parties, and what might some of the impacts be of stakeholder engagement?

Reviewer 4

The reviewer felt that overall, more discussion of planned validation of the models is needed. The reviewer-only slides showed the results of the validation of ATLAS-V1, and not many details are provided for V2.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said the ability to predict potential mobility and energy impacts of new transportation technologies and services is critical for the VTO, the EEMS subprogram, and other relevant agencies in deploying or guiding these technologies and services in a sustainable and equitable fashion.

Reviewer 2

The reviewer mentioned vehicles and energy-efficient mobility systems are a huge component of overall energy consumption, GHG generation and equity challenges. Optimization of said systems is complex and interdependent. This project addresses exactly that complexity and is very relevant.

Reviewer 3

The reviewer confirmed the project supports the VTO subprogram objectives.

Reviewer 4

The reviewer commented this is a very relevant project. Many simulation projects, while considering human behavior, do not considering the evolution of households and technology options and adoptions.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer noted the project funding is very large, but commensurate with the scope and ambitious goals of the project.

Reviewer 2

The reviewer commented the project is mostly labor. The annual funding is sufficient to support more than a dozen highly-trained full-time equivalent (FTE) staff and is consistent with the "dozens" of (part-time) researchers collaborating on this activity. That level of effort is consistent with the breadth of objectives.

Reviewer 3

The reviewer mentioned the budget is large but it covers what is clearly a substantial modeling effort by a large modeling team.

Reviewer 4

The reviewer stated the team has access to sufficient resources to deliver their project.

Presentation Number: eems093
Presentation Title: Transportation System Impact: POLARIS Workflow Development, Implementation and Deployment
Principal Investigator: Joshua Auld, Argonne National Laboratory

Presenter

Joshua Auld, ANL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

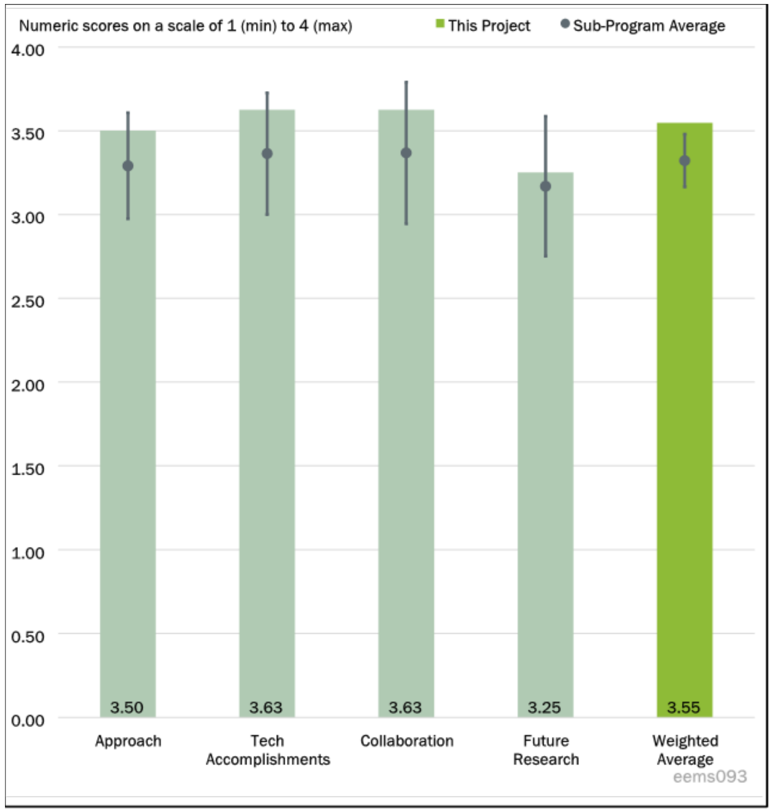

Figure 3-13 - Presentation Number: eems093 Presentation Title: Transportation System Impact: POLARIS Workflow Development, Implementation and Deployment Principal Investigator: Joshua Auld, Argonne National Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer commented that POLARIS-centered workflow encompasses a broad array of features and capabilities that can be used to study a wide range of transportation improvement and decarbonization pathways. The ability to model electric vehicle (EV) charging and grid interaction is appealing, especially in light of the federal effort to create a nationwide EV charging network. Also, the inclusion of freight and multimodal travel at the agent level enhances the realism of the modeling.

It is commendable that the project design is stakeholder-driven, with early engagement to understand needs and regular interaction to receive feedback. The presenter explained that the current approach for technology transfer is based on licensing coupled with direct training and technical support. Perhaps, it is out of the scope of the current project, but additional efforts on model documentation and capacity building may be needed to encourage continued utilization of the workflow by the current stakeholders and adoption of the workflow by new stakeholders beyond the life of the project.

Reviewer 2

The reviewer stated the project is large in scope and well thought out to address the complexity. Many organizations are involved, leading specific applications to answer research questions in their areas of need and expertise. ANL pulling the majority of it together makes sense. The approach of an licensed open-source to ensure almost all modifications by users are piped back into the tool for others to use is appreciated. The licensing will no doubt reduce distribution, but can perhaps lead to a well-controlled tool. The open-source nature supports independent validation. The timeline is reasonable.

Reviewer 3

The reviewer expressed it is not entirely clear if the technical barriers are in reference to past work or future work. With regard to technical barriers that have already been overcome, the slides were not explicitly clear on the challenges faced by the modeling team. However, it is clear from the development of the workflow and the coverage of the results that the team has technical proficiency and no doubt addressed many modeling challenges along the way. In regard to future technical barriers, the project presented upcoming challenges on Slide 43. However, there was not any discussion within the presentation as to how the project members intended to address these challenges. Given the length and time constraints of the presentation, this was understandable, but it would have been good to present an example of how the team's capabilities could overcome these challenges.

Reviewer 4

The reviewer asserted this is a great tool. The approach of engaging stakeholders to identify the gaps and needs, adding new features based on the feedback, improve workflow, and develop scenarios and analyze is a great approach for a project of this scale and size.

*Question 2: **Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.***

Reviewer 1

The reviewer noted the project team has made good progress in which most of the milestones have been met. Notable achievements include incorporation of micromobility modes, modeling of EV charging behaviors, and assessment of equity impact of the tested scenarios. Extensive efforts have been made in calibrating and validating the different components of the workflow.

The presenter discussed the application of the workflow to study the impacts of a variety of transportation technologies and services. There are lots of modeled results. Where applicable, it would be interesting to compare the results from the workflow to those from existing modeling tools at the metropolitan planning organizations (MPOs). It is also encouraging to see cloud computing being explored as an alternative to HPC, which could help lower the barrier to entry for many potential users.

Reviewer 2

The reviewer said the project milestones appear to be well on schedule.

Reviewer 3

The reviewer observed that technical progress has been clearly demonstrated as the slides showed different outputs from a variety of case studies resulting from the POLARIS platform. This is most succinctly shown on Slide 14, with the milestones of the project displayed in great detail. The breadth of the analysis is very impressive and the team does a good job in showcasing this in the presentation. however, besides highlighting the modeling results, it is suggested to also provide an overview of other outcomes of the modeling effort (e.g., publications, policy impact, other real-world actions taken in response to the modeling).

Reviewer 4

The reviewer commented that that currently only 22 users are using this strong tool, which is surprising. Similar to the comment from last year, it seems this tool should be an open source. The team response to this comment from last year is not satisfactory. Free license and open source are very different. Open source will help with development of guidelines and other resources to reduce the learning curve or provide simpler modules for others to use.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer noted that coordinating a multi-partner team in a highly complex project is always challenging, but the progress and accomplishments presented indicate well-coordinated efforts. The integration of multiple models in the framework with automatic handoff of model inputs/outputs can only happen with good collaboration among the partners within the project team. Also, the number of external partners from both academia and industry is impressive.

Reviewer 2

The reviewer intimated there are many cogs in this machine. Again, having a variety of entities lead specific applications is a nice way to distribute the development and validation while also leveraging specific expertise. Licensed open-source is a valid approach to capturing these inputs. Unlicensed open-source could lead to unexpected improvements, but would be much less coordinated. Perhaps there is a later phase where the tool transitions to unlicensed and obtains additional value and insight once the base tool has sufficient momentum.

Reviewer 3

The reviewer found that the project clearly demonstrates a broad array of collaborations being made throughout a variety of industry, MPO, and academic stakeholders. However, it was difficult to gauge the level of effort and interaction with these stakeholders besides their involvement with specific sub-products. While this may again be a product of the length of the presentation, it would be beneficial to delve a bit more into detail on the level of collaboration and what expertise/contributions that stakeholders were bringing to the table (at least providing one or two examples from specific projects). This would give a better sense of the types of interaction and collaboration that are happening between the core project team and external stakeholders.

Reviewer 4

The reviewer noted there are several national labs, universities, and private public partners on the team.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer remarked the proposed expansion of workflow capabilities and applications suggests an ambitious plan, but it is well directed at addressing the remaining challenges and barriers.

Reviewer 2

The reviewer said the proposed work is internally consistent with the overall project objectives.

Reviewer 3

The reviewer stated topics of the proposed future research (Slide 44) are nicely documented and sensible extensions of the existing work. (Although occasionally there seems to be some overlap in topics, it is assumed these may not be fully fleshed out in the current instantiation of the model). In addition to model capabilities, the project team should consider being more explicit about stakeholder engagement and model/results accessibility. It is heartening to see a call out to "documentation, training and support tools", but a greater emphasis on translating all of the modeling work into direct impacts would make a lot of sense.

Reviewer 4

The reviewer observed one of the future works should perhaps be on community engagement with the goal of investigating the roadblock for researchers not adopting POLARIS and increasing the awareness among the researchers.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer stated the ability to predict potential mobility and energy impacts of new transportation technologies and services is critical for the VTO, the EEMS subprogram, and other relevant agencies in deploying or guiding these technologies and services in a sustainable and equitable fashion.

Reviewer 2

The reviewer noted the system of systems level modeling for transportation is directly aligned with VTO and EEMS missions and objectives: energy, GHG and equity.

Reviewer 3

The reviewer said the project clearly supports VTO EEMS objectives, and the breadth of transportation systems that POLARIS covers inevitably overlaps with the goals of the EEMS program.

Reviewer 4

The reviewer confirmed POLARIs is a very relevant tool and the project has clearly shown several existing projects are using it.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated the project is equipped with a large number of resources, but this is reasonable for such a major undertaking by a very large project team.

Reviewer 2

The reviewer felt the annual funding is sufficient to support more than a dozen highly trained/experienced FTE staff, or dozens of part-time researchers. The funding is sufficient to support the number of entities listed and allow for the necessary collaboration.

Reviewer 3

The reviewer remarked the budget seems reasonable. The amount of funding for the project is quite large but this is reflected in the size of the POLARIS team, in the breadth of work and outputs, and the number of research partners that the project team engages with.

Reviewer 4

The reviewer said the team has enough resources to deliver the project.

Presentation Number: eems094
Presentation Title: Development and Validation of Intelligent Connected and Automated Vehicle (CAV) Controls for Energy-Efficiency
Principal Investigator: Dominik Karbowski, Argonne National Laboratory

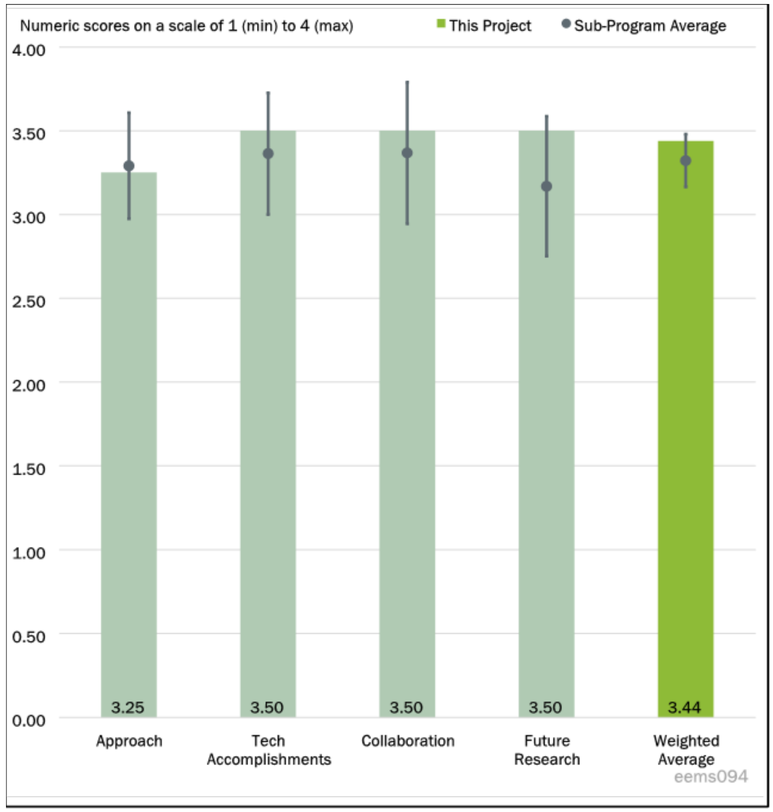

Figure 3-14 - Presentation Number: eems094 Presentation Title: Development and Validation of Intelligent Connected and Automated Vehicle (CAV) Controls for Energy-Efficiency Principal Investigator: Dominik Karbowski, Argonne National Laboratory

Presenter

Brandon Heimer, Dominik Karbowski, ANL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer noted that it is not clear how this project stands alone from others. The need to quantify energy savings of scenarios in the real-world is a clear technical barrier. It is nice to show connections but in the slides and during the presentation it was hard to evaluate the project with clear boundaries to this specific activity. Of course, understanding the connection is important but a better job could be done in clarifying boundaries.

Reviewer 2

The reviewer commented the project does a very good job of tackling the issues related to CAV control with excellent demonstrations of the techniques developed. One issue, which may be outside the scope of the project, is how to deploy the techniques in production vehicles. It seems control strategies are needed that can work effectively just by communicating standard commands/signals rather than reaching into vehicle powertrains for direct control.

Reviewer 3

The reviewer mentioned the project does an excellent job of addressing stated barriers. Project achievements are directly tied to stated technical barriers: improving CAV energy efficiency for diverse powertrains and evaluating CAV energy use by defining test scenarios and methods.

Reviewer 4

The reviewer stated the project laid out the important groundwork to eventually overcome all planned technical barriers. Even though the principal investigator (PI)is confident the project will achieve all its goals, there is concern over one really hard barrier: "Real-world implementation requires diverse experimental vehicles and new test procedures" As a result, this barrier might take longer to resolve than originally planned.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer remarked the team clearly demonstrated progress in testing CAV methods including demonstrations in lab and on track with XIL. However the energy benefits discussion was hard to follow during the presentation and the slides do not support a clear understanding.

Reviewer 2

The reviewer said the team provided an excellent demonstrations of the project deliverables. The project is on schedule.

Reviewer 3

The reviewer noted the project team achieved impressive validation results compared to simulation across a wide variety of scenarios thanks to automated test procedures in simulation and XIL. Technical maturation was very comprehensive as it grew from simulation-only to dynamometer to track, and results at each stage showed very good understanding and control of all the test parameters. The technical findings are also well-explained in the slides. Further, the adaptive cruise control (ACC) engagement analysis is intriguing. Could this type of analysis be applied to help define an operational design domain (ODD)? It is crucially important that vehicles be able to recognize when they are outside their ODD as well as within it and that this be done with sufficient time if the systems require human intervention. Finally, it is unclear if the energy-evaluation test methods or test scenarios (or even just lessons learned) are being promulgated anywhere outside of ANL.

Reviewer 4

The reviewer expressed the project made planned progress. The preparatory work under "Math-to-lab-to-road" is positive, and convincing. The project results feed into other EEMS projects as subtasks (listed on Slide 4). Such subtasking is useful to achieve more effective execution of the project, and it is shown in the accomplishments to date.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said the team seems to be well integrated, and coordination with the PI seems strong.

Reviewer 2

The reviewer commented the project has an excellent group of partners with a logical division of labor and good processes for transferring work.

Reviewer 3

The reviewer asserted the collaborations with Clemson, University of South Florida, and ACM appear very strong.

Likewise, the General Motors (GM) cooperative research and development agreement (CRADA) is very encouraging, although the scope of the CRADA is unclear. Does it cover just the GM-provided data on ACC engagement, or is GM also interested in implementing the algorithms developed by the PIs of this project?

Reviewer 4

The reviewer observed the project has strong partners that seem to coordinate well. It is important to have not only academic partners (four of them) but also the key industrial partner (GM) which provides real vehicle data for verification of simulations.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer stated the proposed future work, including the on-track real-world testing, is appropriate and does support achieving the project targets.

Reviewer 2

The reviewer said the project's next steps are well defined and the work appears on track to meet the project goals.

Reviewer 3

The reviewer noted the proposed future work is a logical evolution of research and progress made to date. Given the project's progress and strong performance from simulation to road testing, it would be good to see a stronger emphasis on potential technology transfer.

Reviewer 4

The reviewer mentioned the proposed future research is clearly defined and challenging, yet achievable. Specifically, the idea of implemented AI based CAV control is well-received. It is believed that the team plans to employ a Reinforcement Learning (RL) based controller, which is indeed a popular method of on-line intelligent control. It is recommended the team assess how much data is needed to control CAV by RL to reduce the amount of trial and error typical of RL algorithms. It is further recommended that combining different XIL (anything in the loop) needs to be analyzed carefully as such systems can cascade down much more uncertainty than expected, sometimes resulting in outcomes much worse than expected in preliminary experiments.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer maintained that quantifying energy benefits in real-world scenarios is critical for adoption of CAV techniques in future vehicles.

Reviewer 2

The reviewer commented CAV controls activity is central to EEMS technology development, of which CAVS is one of the pillars. The work is necessary to make CAVs viable and is useful for not being proprietary, as most CAV activity currently is.

Reviewer 3

The reviewer remarked the project seeks to quantify and improve energy efficiency of CAVs, which aligns with EEMS goals.

Reviewer 4

The reviewer confirmed the project is highly relevant to the goals of EEMS as it studies how to improve energy efficiencies of connected and automated vehicles.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer noted the team clearly has the technical and facility resources necessary to achieve the milestones.

Reviewer 2

The reviewer said the project appears well funded, with no delays due to lack of resources.

Reviewer 3

The reviewer affirmed that resources appear sufficient since the project is on schedule and meeting its deliverables.

Reviewer 4

The reviewer stated the project resources are sufficient to achieve all proposed milestones.

Presentation Number: eems095
Presentation Title: Integrated Control of Vehicle Speeds and Traffic Signals for Reducing Congestion and Energy Use
Principal Investigator: Timothy Laclair, Oak Ridge National Laboratory

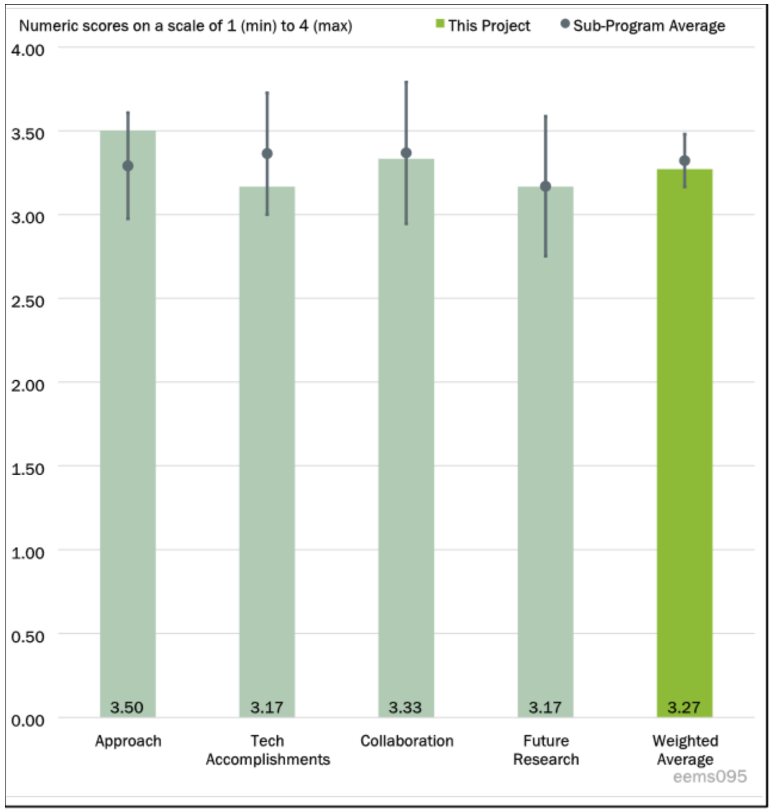

Figure 3-15 - Presentation Number: eems095 Presentation Title: Integrated Control of Vehicle Speeds and Traffic Signals for Reducing Congestion and Energy Use Principal Investigator: Timothy Laclair, Oak Ridge National Laboratory

Presenter

Timothy Laclair, ORNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer mentioned the researchers identified clear barriers and objectives in developing vehicle based optimization relying on traffic signal timing information. It is unclear whether the team assumptions about DSRC/cellular vehicle-to-everything (CV2X) radio communication range are correct (100-200m); this seems quite short unless in dense downtown type environments. The challenges of cellular backend database management are also good to note.

Reviewer 2

The reviewer commented that assuming Slide 6 has a typo and the actual milestone date for functioning speed control algorithms is September 2022, project milestones appear to be on schedule and achievable. The last milestone occurs in March 2023. Is that really the last milestone before the project ends in September 2023? Also, the control algorithm is scheduled for deployment to Shallowford Road by March 2023; the project team may want to add a milestone review with City of Chattanooga to ensure the state/local DOT has reviewed and is comfortable with the deployed software.

Reviewer 3

The reviewer stated the project is using a sound approach, employing simulation, hardware in the loop, and on-road testing to develop and analyze the potential of cooperative traffic signal and vehicle operations to save energy.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer observed good progress in speed control strategies. The results of signal timing effect are not very clear, although the test of RyThMiCCS is good to see.

Reviewer 2

The reviewer noted the slides do a poor job summarizing the technical efforts investigated. Part of the confusion seems to stem from inconsistent/unexplained nomenclature. For instance, the bi-linear and queue-aware eco-driving algorithms are introduced in the slides without any context about what they are (centralized/cellular or decentralized/direct communications), albeit it was eventually verbally reported that they are both decentralized control algorithms. Likewise, it was only verbally reported that the centralized control was a “simple baseline algorithm.” On Slide 14, it would have been helpful to show performance plots side by side (or on subsequent slides) rather than through PowerPoint animation (which was only visible during the AMR presentation). There was also no clear takeaways about which demonstrated the best performance (although after reviewer questioning, it was verbally reported as distributed algorithm with queue prediction). On Slide 15, tables and figures are not consistently labeled with axes and units, which muddies the technical impact of the work. The technical work may be excellent, but the presentation of it was rather sloppy. Finally, assuming the tabulated technical results on Slide 15 are % energy savings, the results appear promising even for low penetration rates and the implementable queue. Is there a technical explanation for why eastbound and westbound results are significantly different from each other?

Reviewer 3

The reviewer remarked the team is making good progress on the technical accomplishments and milestones. One area that the team cited as having some uncertainty is the readiness of the CAVE laboratory environment.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said the project exhibits appropriate team members and seemingly good coordination by team leaders.

Reviewer 2

The reviewer noted that while Toyota is listed as a partner, it seems the company is primarily participating by supplying the test vehicles. There were no references to active collaboration with Toyota, nor any interest cited in furthering the development effort. The same can be said for Cubic, in that their equipment and maybe IT support is being used, but it is unclear how involved the company is in the research or its findings. In contrast, Chattanooga seems like a more involved partner, as the tests took place on active roads.

Reviewer 3

The reviewer mentioned the team includes members from the automobile OEMs (Toyota), the traffic signal control equipment vendor community (Cubic/Gridsmart), and a local transportation agency (City of

Chattanooga). This diverse team is very important in both the development and demonstration phases of the project. If successful, these team members are also key for outreach on further advancing this topic.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer asserted the project has a clear and appropriate future work plan that seems likely to enable the team to achieve its targets.

Reviewer 2

The reviewer expressed the project has identified some major challenges and barriers for future research, mostly related to interoperability and the complexity of deploying such new technologies. However, the proposed future research is focused predominantly on refining the algorithms and does not address these deployment challenges. It is important that the proposed research not become overly academic and insufficiently demonstration-focused.

Reviewer 3

The reviewer felt the future work is supportive of the project goals and includes leveraging work from other EEMS projects (EEMS101 and EEMS061).

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer suggested that integrating CAV functions in real-world traffic corridors will require integration with signal control to some degree. This project addresses that need.

Reviewer 2

The reviewed commented the use of controls and communications to improve energy use of CAVs very much aligns with EEMS goals.

Reviewer 3

The reviewer said the project is very relevant to the EEMS program and is developing and testing vehicles that interact with the traffic control system to operate in a more fuel friendly manner.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated the team has the resources needed to complete the project.

Reviewer 2

The reviewer confirmed the project appears sufficiently funded and staffed; its milestones have been achieved on schedule.

Reviewer 3

The reviewer mentioned the resources appear to be adequate to accomplish the project goals.

Presentation Number: eems096
Presentation Title: Characterizing Behaviors and Capabilities for Emerging Connected and Automated Vehicle Technologies, Sensors, and Connectivity
Principal Investigator: Thomas Wallner, Argonne National Laboratory

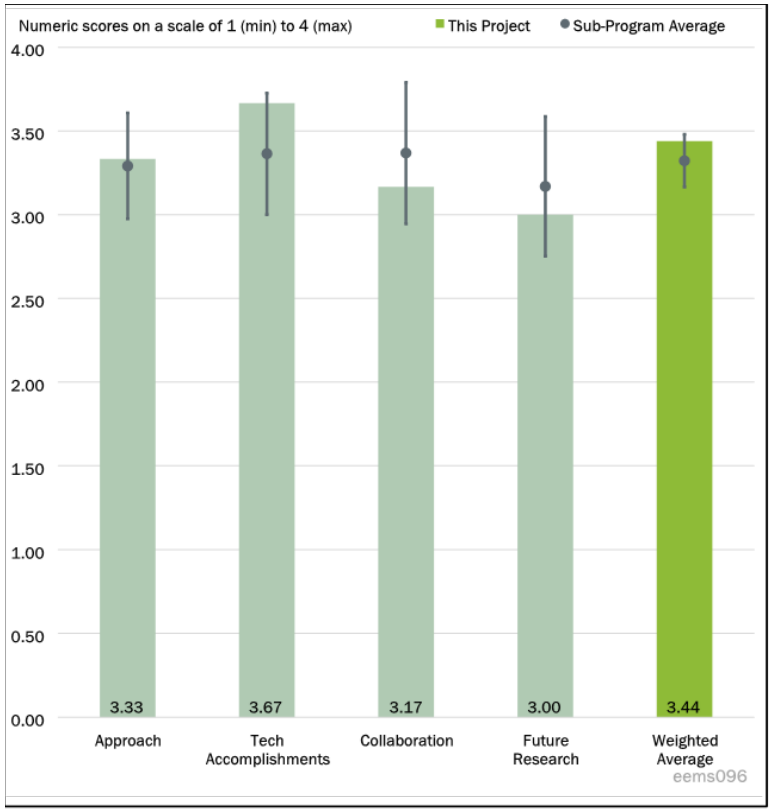

Figure 3-16 - Presentation Number: eems096 Presentation Title: Characterizing Behaviors and Capabilities for Emerging Connected and Automated Vehicle Technologies, Sensors, and Connectivity Principal Investigator: Thomas Wallner, Argonne National Laboratory

Presenter

Thomas Wallner, ANL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer commented the project is well designed and ingenious in extracting as much information as possible given limitations on available information, which is mostly proprietary.

Reviewer 2

The reviewer offered that feedback on the testing framework is compiled in June 2022, but then is not delivered until September 2023. The project team may want to move the latter milestone earlier, if possible, as the engagement with external communities should happen as early as possible to: 1.) ensure alignment, and 2.) not miss timely opportunities to provide input.

Reviewer 3

The reviewer stated the project goal is unclear. Is the primary/final focus on data itself, analysis results of the collected data, or some form of a synthesized model for connected and automated vehicles? On the “APPROACH” slide, the last box states “Experimental Testing and Evaluation Methodology Investigation”. However, I do not see sufficient details for this box itself, other than three boxes that lead to this one.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer remarked the technical progress has been impressive. Starting almost from scratch, the team has done great work in setting up the test properties and acquiring the data needed.

Reviewer 2

The reviewer noted the new collected datasets of production (Tesla, GM SuperCruise) L2+ features should be very useful to cooperative driving automation (CDA) researchers. The list of collected signals looks quite comprehensive; if radar/lidar and object tracking lists are also recorded, these types of datasets may also have great relevance for USDOT safety researchers. In addition, NREL's recruitment of shared data from Locomation and Cummins will undoubtedly be highly sought after, as OEM data is usually very difficult to obtain. The sensor data collection effort highlights how models can vastly differ from reality if modelers assume manufacturer specs/descriptions at face value. Moreover, manufacturer characterizations may take place in very different operating environments relative to where they are actually deployed. Such findings demonstrate the high value of projects like these. Lastly, testing standards definitely need to be tightly plugged into SAE standards development efforts.

Reviewer 3

The reviewer observed that progress shown on the "MILESTONES" page does not seem to perfectly match the progress implied in the Budget section, i.e., expended budget so far. It appears like more than one-third of the total tasks is still remaining.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer noted excellent collaboration between industry (medium-/heavy-duty) and national labs and among the labs. Most of the required partners for success are onboard.

Reviewer 2

The reviewer asserted partnerships among the national labs appear very strong. It is recommended that the team also make sure the SAE standards participation is equally as strong.

Reviewer 3

The reviewer stated it is fascinating that the project team has already established the connection with a couple of partners for MD/HD duty connected/automated vehicle data collection. There is a question as to whether the team has a test and evaluation plan for data collection with Cummins Inc and Locomation? For example, how many runs does the team plan to conduct? Will the data collection be conducted during actual business operations, or will this be a separate test run just to collect the data? Does the team have any evaluation matrix defined (this is needed to determine which data should be collected)?

Especially for the data collection plan with Locomation testing, it should be noted that the Operational Design Domain (ODD) of the Locomation testing includes only ideal conditions (e.g., four or more lanes with a shoulder, free flow, good weather, no physical obstacles (such as tolls and work zones), etc.). With that in mind, if the project team's intention is to collect the data for various traffic conditions, there should be an additional effort to design additional cases for this purpose. Lastly, the Locomation testing this year will likely use a human driven lead truck followed by an L2 truck (not L4/L5).

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer state next steps are a logical continuation and extension of the project work done to date.

Reviewer 2

The reviewer commented that for the connectivity characterization, the team should first review what US DOT (will have) released for Intelligent Transportation Systems—Joint Programs Office (ITS JPO) CV2X testing data and analysis to avoid reproducing work. It would also be helpful to begin identifying and connecting with potential end users to understand how they might use this data. For instance, do users envision POLARIS updating models, or is this mostly data to release to university researchers? Will MPOs be building their own analysis tools, or is this for regulators trying to better understand performance of these technologies?

Reviewer 3

The reviewer remarked the proposed future research is defined clearly enough. However, it would be challenging to complete at least two of the future work elements. For M/HD data collection and testing, it appears the team is still doing the negotiations with the selected partners, which will take lots of effort and time. This is true especially if those negotiations are to result in a test and evaluation plan. In addition, the project team seems to lack understanding on the Locomation testing plan. For expanding sensor characterization to connectivity, it may be challenging to include C-V2X unless the project team already has an established environment for this.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer deemed the project relevant to EEMS and the connected autonomous vehicle technology pillar. It also supports the Vehicle Analysis program objectives with real-world data.

Reviewer 2

The reviewer stated the project collects real-world hardware data to refine and reduce variabilities in modeling and simulation efforts, which is a very desirable activity to reduce modeling uncertainties as the technologies mature.

Reviewer 3

The reviewer concluded the project supports overall VTO subprogram objectives. In particular, the results should be useful for two subprograms (Vehicle Analysis and EEMS).

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said the funding appears adequate. The researchers have done an excellent job of maximizing “bang for the buck”.

Reviewer 2

The reviewer commented the resources (funding, staffing, materials) appear sufficient, as the project has already begun producing actionable data.

Reviewer 3

The reviewer intimated that it is difficult to tell if the resources are excessive, sufficient, or insufficient just based on the presentation content. However, the reviewer has concluded that the funding is more than sufficient to cover what was presented.

Presentation Number: eems097
Presentation Title: Micromobility-Integrated Transit and Infrastructure for Efficiency (MITIE)
Principal Investigator: Andrew Duvall, National Renewable Energy Laboratory

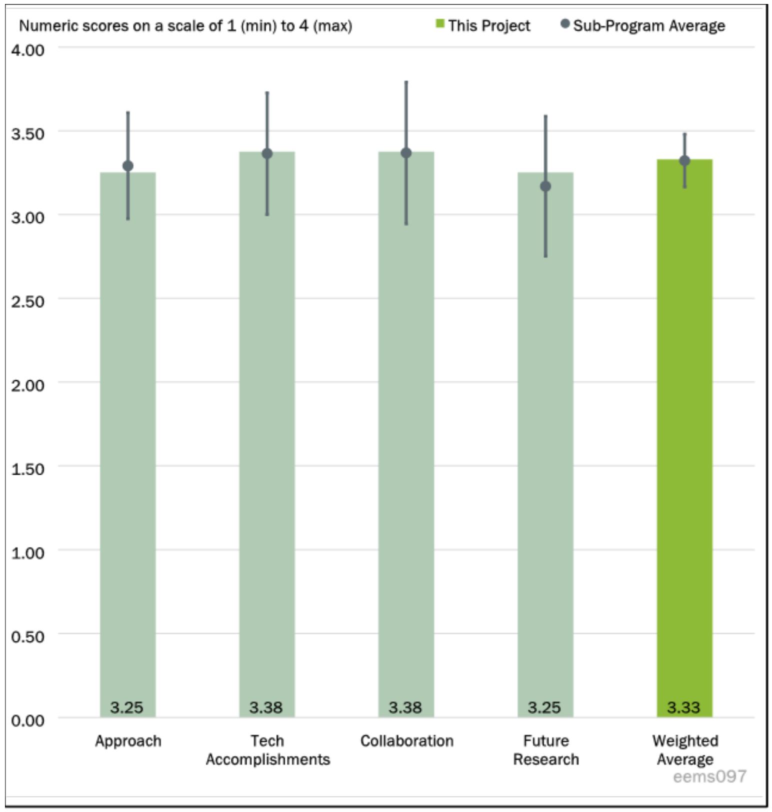

Figure 3-17 - Presentation Number: eems097 Presentation Title: Micromobility-Integrated Transit and Infrastructure for Efficiency (MITIE) Principal Investigator: Andrew Duvall, National Renewable Energy Laboratory

Presenter

Andrew Duvall, NREL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer indicated that researchers have a seemingly well designed approach and have made good progress and reaching the project objectives.

Reviewer 2

The reviewer commented that the project augments SMART Mobility by enhancing workflow models to include micromobility based on real-world data. It addresses technical barriers working towards ranges of micromobility assumptions and transit interconnection while accounting for location and demography. Within SMART Mobility efforts, this project integrates with BEAM CORE (informing scenario integration), freight (microfreight), and curb space (curb activity impact of micromobility and microfreight).

Reviewer 3

The reviewer stated the technical barriers were identified in Slide 2, with two primary barriers: uncertainty in future demand scenarios for micromobility, and a better characterization of MEPs. The first issue was nicely addressed, specifically with the consideration of low/medium/high scenarios (Slide 3) and the discussion of low and high possibilities of energy impacts (during Slide 8). The second, involving the characterization of MEPs, was not discussed in the remainder of the presentation.

Reviewer 4

The reviewer mentioned the project appears to be logically planned and the timeline is reasonable. More detail regarding the microfreight task would be appreciated. For instance, what are the volumes and weights of the micro-freight packages? What is the max capacity of micro-freight per scooter? How does the modeling account for multi-stop routes? Does the microfreight energy consumption modeling include increased weight of the microfreight load and increased aero-drag due to microfreight packages? On the demand side, what is the current count or percentage of package deliveries that would qualify for microfreight delivery?

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer noted the authors have made good progress in moving from model development to scenario implementation, with modeling for several cities, and data from a larger group of cities (despite the limited amount of data in the area).

Reviewer 2

The reviewer stated the project has progressed in all five tasks. In Task 1, the first publication in energy bounds estimation for shared mobility was developed along with ongoing conversations with the BEAM and POLARIS teams. Task 2 analyzed micromobility trip data from docked bikeshares in 11 cities and dockless bike/scooter share data in 10 cities. Task 3 established a behavior model that estimates how people chose micromobility modes. Task 4 evaluated micromobility operations for energy optimization including e-scoter in-field data acquisition. Task 5, drew microfreight scenarios from cargo bike pilots in Seattle and NYC.

Reviewer 3

The reviewer expressed the breadth of technical accomplishments is very impressive, including the peer-reviewed publication for energy demand characterization of shared micromobility options. The accomplishments nicely complement the project objectives identified on Slide 3. One suggestion is that given the importance of extending the results to other cities, it would be good to see an explicit treatment of the calibration to cities (and validation if possible).

Reviewer 4

The reviewer noted the impacts of covid are understandable and valid but the team has the option to make assumptions regarding the missing data and push forward. The project may benefit from a workshop where subject matter experts and experimenters talk through hypothetical scenarios and modeling assumptions, and results are discussed in detail with stakeholders. This exchange would be useful for helping the team to validate its assumptions and get feedback from stakeholders.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said the team incorporates a good group of researchers from national laboratories, U.S. Environmental Protection Agency (EPA), academic partners, and cities. The work is also being incorporated into BEAM. It will be exciting to see how the model can be integrated into city planning as it continues to develop.

Reviewer 2

The reviewer asserted good collaboration among NREL, ANL, and PNNL in addition to several non-lab research partners including University of Colorado-Boulder, EPA, USDOT, University of Tennessee, and Portland State University. Additionally, the MITIE team continues to engage with industry stakeholders and identify data sources and complimentary partners. The team collaborative relationships are essential to gain access to data and to understand needs and trends.

Reviewer 3

The reviewer commented that efforts of the team across the national laboratories were well documented, and the portions of the project and contributions of the various researchers were nicely articulated during the presentation. However, the collaborations with other external stakeholders are not entirely clear. Besides data acquisition, it was not clear how stakeholders such as academic institutions and industry stakeholders are involved with the project and whether there are other types of contributions. It would be useful to be more explicit about the types of collaborations that are happening with the project team (even in the backup slides, that is, Slide 23, this is not clear).

Reviewer 4

The reviewer said the team appears to have attempted to collaborate with a large number of stakeholders on this project.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer stated the researchers have made good progress in the scenario development for micromobility, and are meeting the project milestones. It appears that the authors have a few more tasks to accomplish, but are well on their way to successful project completion. It would be interesting to see what work the authors would propose beyond done in the current project.

Reviewer 2

The reviewer noted the fiscal year (FY) 2022 milestone includes development of micromobility scenarios for smaller representative cities while continuing in-field data collection. The FY2023 milestone includes the final report with estimation of net energy use of micromobility and energy consumption and sensitivity analysis on the tested micromobility vehicles.

Reviewer 3

The reviewer observed the proposed future research seems rather brief and primarily focused on wrapping up the analysis and producing a final report. It is suggested that the project team explicitly consider dissemination of findings (and perhaps even provide custom modeling efforts) to interested stakeholders (as was discussed in the question and answer). On Slide 19, the project identifies the potential to address mobility for equity considerations with micromobility; this can be an important aspect of stakeholder engagement and would align with DOE objectives to address equity issues in mobility.

Reviewer 4

The reviewer stated the future work stated appears to be within the scope of the current project. A couple of bullets on logical follow-on targets for investigation are also suggested. For instance, microfreight can also be delivered by unmanned aerial vehicle (UAVs); how does scooter microfreight energy consumption compare to UAVs? How does microfreight delivery energy consumption change when the scooter is autonomous?

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer noted the area of micromobility is going to be an important piece of developing an overall strategy for improving mobility options going into the future. Micromobility will also be important in developing strategies around first and last mile solutions for bus and rail transport users. This project should provide some important information on filling the gaps on micromobility. The authors also have a nice summary slide on this topic in the presentation.

Reviewer 2

The reviewer commented that the research supports EEMS by advancing technologies and systems to improve MEP when adopted at scale and exploring modes whose energy impacts have not been well studied. In turn, micromobility with clean energy technology to move people and goods can reduce energy costs and increase energy security.

Reviewer 3

The reviewer said the project aligns with VTO objectives.

Reviewer 4

The reviewer confirmed the work is relevant to the VTO EEMS mission.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

Overall, the reviewer stated the project has sufficient resources for completion with the potential for future expansion assuming additional funding down the line.

Reviewer 2

The reviewer thought the budget seems appropriate for the 3-year micromobility project scope and multiple partner involvement.

Reviewer 3

The reviewer mentioned the budget of the project seems commensurate with the modeling efforts and size of the project team.

Reviewer 4

The reviewer remarked the project shows evidence of making reasonable progress based on current funding.

Presentation Number: eems098
Presentation Title: Optimizing Drone Deployment for More Effective Movement of Goods
Principal Investigator: Victor Walker, Idaho National Laboratory

Presenter

Victor Walker, INL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

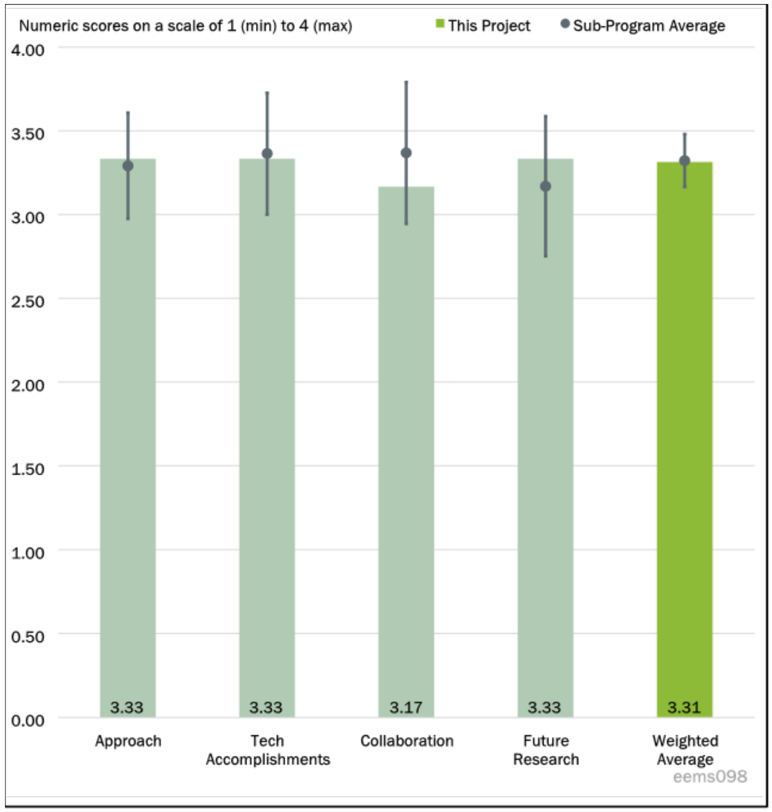

Figure 3-18 - Presentation Number: eems098 Presentation Title: Optimizing Drone Deployment for More Effective Movement of Goods Principal Investigator: Victor Walker, Idaho National Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer commented that the project initially gave the impression that it its scope was too large; however, the practical insights that have been developed to date indicate that the project plan has its merits.

Reviewer 2

The reviewer stated the approach is to develop a detailed test plan for drone testing, identify primary scenarios, complete environmental and energy testing of drone hardware, gather data for route optimization, and investigate various operating scenarios. This is a sound plan and covers various aspects of drone deployment and use.

Reviewer 3

The reviewer said the project approach appeared well thought out in addressing technical barriers of drone technology and gaining greater understanding of drone behavior and delivery applications. The project timeline appears to have been well planned with completion in sight later this calendar year. As outlined by the PI, the approach involved a combination of open-environment, lab-based testing for input into simulation models and eventual validation of those models. The PI appeared to address previous reviewer comments for ensuring industry collaboration for test protocols and simulations and drone selection (small/large and rotary/vertical take-off and landing [VTOL]) for most relevant real-world application and market representation.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer remarked the technical accomplishments are impressive from the standpoint that the work include data collection, model formulation, scenario development, and analysis. Moreover, the insights generated have utility for real-world applications.

Reviewer 2

The reviewer noted the technical accomplishments are sound and include drone instrumentation and field testing on a broad range of operations, energy data analysis, weight and speed impact studies, and evaluation of operating scenarios.

Reviewer 3

The reviewer expressed the project has made significant technical progress towards original objectives as presented by the PI. The PI presented interesting findings on drone energy use overall, as well as insights for drone sizes and drone types. The results also included interesting insights on drone speeds and payloads for optimal energy use, possible preferential or infeasible duty cycles/routes for rotary and VTOL drones, and how mixed fleets may offer greater utility and lower energy profiles. Finally, the business-business delivery scenario insights are useful in the application of different drone types and understanding of alternate advantageous charging options.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer mentioned that collaborations appear to be very effective for addressing this problem space.

Reviewer 2

The reviewer noted the team has shown broad collaboration and cooperation with primary partners such as Wing, Spright, Interpath, Wingcopter and CMU, as well as various other supporting partners such as Workhorse, UPS, Virginia Tech, etc.

Reviewer 3

The reviewer commented that overall, the project has significant collaborative partners across manufacturers, service providers, delivery companies, government institutions, and universities. While the PI did confirm industry partner collaboration regarding model data, additional specificity on partner contributions across project elements including testing, simulation, and validation would have been useful.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer stated the future work that is outlined is logical and important for this activity. The validation and open air experiments are especially important.

Reviewer 2

The reviewer noted the proposed future work plan focused on modeling, validation, and communication is well-motivated.

Reviewer 3

The reviewer indicated that the remaining proposed research activities under the project appear reasonable in accomplishing project objectives. Remaining activities include completion of model integration, Scenario 3 (delivery as a service) completion, simulation validation through open-air testing, and outreach through partners. It is assumed the final report will include discussion and insights on the many research challenges encountered on the project including drone selection, environmental impacts, metrics development, partner requirements, and additional data/sensor requirements for future drone research efforts.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said drone delivery has relevancy in the transportation market place and DOE should understand its energy consumption characteristics to be able to predict future benefits/impacts and possible technology development needs.

Reviewer 2

The reviewer observed the project supports the overall VTO subprogram objectives of minimizing energy consumption for the movement of people and goods. The study has identified certain scenarios wherein a combination of large and small drones would be more optimal than using traditional delivery trucks. This is a powerful result, especially with the quantitative supporting information the authors have provided.

Reviewer 3

The reviewer felt the project is relevant to VTO's EEMS subprogram and fits under the Multimodal freight (MMF) pillar of the Systems and Modeling for Accelerated Research in Transportation

(SMART) Mobility Consortium. Specifically, this project is providing significant insights on future drone energy use and utility for the U.S. freight industry.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said the project has been very productive with the current resource allocation.

Reviewer 2

The reviewer noted the approved funding is appropriate for this project.

Reviewer 3

The reviewer confirmed the resources for this project appear to be sufficient for achieving project objectives and significant research results within the original project timeline.

Presentation Number: eems099 Presentation Title: Metrics for Assessing the Impacts of Energy-Efficient Mobility Systems Principal Investigator: Venu Garikapati, National Renewable Energy Laboratory

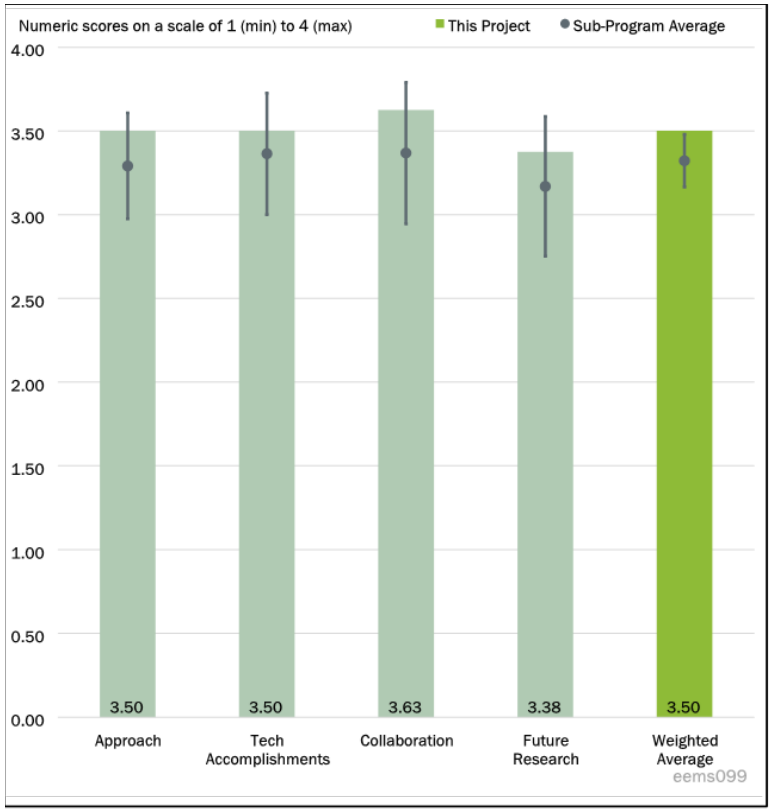

Figure 3-19 - Presentation Number: eems099 Presentation Title: Metrics for Assessing the Impacts of Energy-Efficient Mobility Systems Principal Investigator: Venu Garikapati, National Renewable Energy Laboratory

Presenter

Venu Garikapati, NREL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer noted that MEP provides a unified framework for quantifying mobility and energy impacts of transportation investments and technologies. The new capabilities of MEP, such as variation by time of day and multi-modal routing, improve the utility of the metric. The person-based Individual Experienced Utility-based Synthesis (INEXUS) metric is an interesting concept, and is intended to complement the location-based MEP metric. There are three related but different types of INEXUS metrics. It will be important to clearly explain the purpose and interpretation of these different INEXUS values.

Reviewer 2

The reviewer commented that this work is an important tool for connecting the MEP concept in a practical way with the needs of policy makers/decision makers. The timeline is reasonable, assuming that infrastructure investments are sustainable, where this analysis will be useful.

Reviewer 3

The reviewer stated the authors seem to have a well thought out approach to performing the work. The team has made good progress in enhancing the development of the MEP calculations. These data analyses are worthwhile in breaking down technical barriers in understanding questions related to mobility.

Reviewer 4

The contractor remarked the work plan appears to be appropriate and well-focused. This area is so important that getting in-depth technical review by outsiders should be part of the activity. Part of the plan that may be missing is to dumb down some of the technical presentations to more clearly explain critical relationships that are included in the work. Does the project produce technical papers to explain the processes and cost functions that are being applied?

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer commented the project team has made several improvements to the MEP metric, which increase the utility of the metric. The interactive dashboard that has been developed will be a very useful tool for comparing and visualizing the results. Also, can data from the Whole Traveler survey be used to support/augment the estimation of the energy decay coefficient?

Reviewer 2

The reviewer stated that progress to date is good in relation to the planned activities. The SMART/MEP enhancements planned for FY22 (emissions, safety), however, may involve much more time/resources to be successful.

Reviewer 3

The reviewer observed that the performance metrics have been met for this project, or are on track to be met. The milestones for the second year appear to be completed or on track, and the project appears to be on the way to successful completion in the third year.

Reviewer 4

The reviewer noted the project is productive in advancing the evolution of the MEP metric.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer remarked there are collaborations with a variety of organizations (government, non-profit, university, and industry). The inclusion of MEP in American Council for an Energy-Efficient Economy's (ACEEE) Scorecard and the commercialization project with Streetlight Data are impressive.

Reviewer 2

The reviewer felt that team collaboration to date seems effective. Collaboration with EPA will be needed for FY22 to link emissions enhancements with existing tools (i.e., MOtor Vehicle Emission Simulator [MOVES] model).

Reviewer 3

The reviewer mentioned the team has good coordination and cross collaboration. The team is a strong mix of national laboratories, state DOTs, and industry partners. The fact that the team has run the calculation for over 100 cities suggests that the results could be useful to a wide range of outside entities. It will be interesting if the researchers can continue increasing the number of partnerships with other more regional government entities or cities as the project evolves.

Reviewer 4

The reviewer noted that collaboration with partners appears to be generating strong return on investment for expanding inclusion of MEP in DOE's models and for application of the MEP to real-world problems.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said the proposed future research listed on Slide #20 is focused on continuing/completing the progress made to date. It is unclear whether and how the remaining challenges and barriers listed on the previous slide will be addressed.

Reviewer 2

The reviewer stated that future research goals, including incorporating emissions, infrastructure quality and safety, seem overly ambitious—at least if done well in a way that will be robust and reliable. Livable cities, especially in the European Union, have focused attention on noise. Adding acoustic emissions to project may be useful as a long-range goal.

Reviewer 3

The reviewer commented that the researchers seem to have a good plan in moving forward with their work on the individual-level MEP metric, enhancements on emissions and safety, and incorporation of the MEP calculation into POLARIS and BEAM.

Reviewer 4

The reviewer noted that the 'carry out assessment of additional factors to include the MEP metric calculation' is of strong interest. This work deserves to be validated and refined further.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer commented that the ability to quantify and compare mobility and energy impacts of transportation investments and technologies is critical for the VTO, the EEMS subprogram, and other relevant agencies in assessing those investments and technologies.

Reviewer 2

The reviewer remarked the MEP metrics are relevant for establishing a comparative basis for assessing mobility needs in urban areas using the SMART model.

Reviewer 3

Overall, the reviewer noted this metric is showing a widening influence, and is having a useful impact on characterizing mobility. Given the importance of understanding mobility in a changing landscape of transportation options throughout the country, this work appears to be well positioned to support DOE's overall objectives.

Reviewer 4

The reviewer said the project is highly relevant to evaluating energy productivity of transportation systems.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer mentioned that based on project efforts, both already made and planned for the future, the level of project funding is reasonable.

Reviewer 2

The reviewer believed the resources have been sufficient to date, but there are concerns that the future work on model enhancements may require additional resources

Reviewer 3

Overall, the reviewer stated that this project has sufficient resources for completion, with the potential for future expansion with additional funding down the line.

Reviewer 4

The reviewer deemed project resources are sufficient to reach the stated milestones. That said, the continuing development of this metric deserves additional funding by DOE.

Presentation Number: eems100
Presentation Title: Dynamic Curb Allocation
Principal Investigator: Chase Dowling, Pacific Northwest National Laboratory

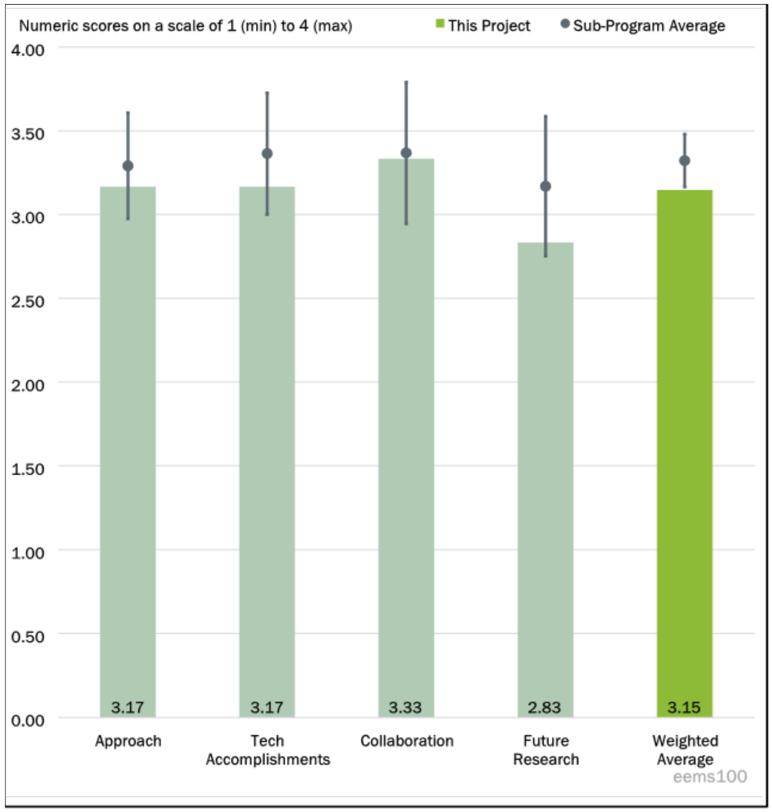

Figure 3-20 - Presentation Number: eems100 Presentation Title: Dynamic Curb Allocation Principal Investigator: Chase Dowling, Pacific Northwest National Laboratory

Presenter

Chase Dowling, PNNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer noted two milestones, M7 and M8, seem delayed, but the presentation does not address the benefit of the delay (e.g., the delay for M7 will double the number of participants). It is important to understand the benefits of the delays in order to justify them.

Reviewer 2

Overall, the reviewer felt the project is well designed to take an initial step toward addressing the impacts of curb use on traffic flow. However, it is not clear if the simulations that were conducted to develop the fundamental diagrams have been validated with real-world data. Additional information on the validity of the simulations of curb use would be useful.

Reviewer 3

The contractor stated the project addresses some interesting barriers: how to propose changes when A/B testing is not a feasible option, and how to have an adoption be seamless for drivers who might not be able to adapt to new technology. One additional potential barrier is adoption by local municipalities, which could be a challenge if the main reason to adopt policy changes would be advice from a research project. What kinds of evidence can the team produce that could convince local policy makers to adopt proposed policies, and what would be the payoff? How can the research recommendations be translated into payoff decisions by local governments?

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer stated that it is not clear how the financial burden to the jurisdiction (e.g., technology needed to measure, data analytics personnel, enforcement, and system maintenance) are considered in the optimization of the process of dynamic curb allocation. Is the benefit the same regardless of the jurisdiction size? What type of minimal infrastructure is needed to ensure it works as intended.

Reviewer 2

The reviewer noted the project is making good progress. As presented, the lack of the planned curb occupancy data from San Francisco may have an impact on schedule as new project partners are sought.

Reviewer 3

The reviewer comments the approach uses microsimulations with VISSIM to estimate vehicle travel on a simulated grid, and then macrosimulation environments (BEAM) to estimate energy use based on changes in policy. This is a reasonable, and the additional approach element that adjusts different zones for buses, etc. in individual grids can be used to explore how changes can be made and their different behaviors interpreted. There are still two concerns, one of which will be delivered in the June 30th milestone: how to validate the microsimulation data based on information gathered from tests. If the microsimulation agrees, then the tool could be very useful. If there is a big difference, then there is a risk that the proposed changes might not be actualized, and the resulting policy will not pay off as expected.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer stated the project has a lot of moving pieces, but it seems it is under control. Once other members/participants (sensors/devices) are available, it will be important to see if the process continues to work as intended.

Reviewer 2

The reviewer expressed the team appears to have good collaboration and coordination. However, the team is also seeking a new local partner that can provide access to curb occupancy sensor data.

Reviewer 3

The reviewer commented the team has partners in Lawrence Berkeley National Laboratory, National Renewable Energy Laboratory, University of Washington Urban Freight Lab, Penn State University, and Lacuna (a startup). The simulator design, fundamental diagram learning techniques, usage of BEAM, and the optimization metrics, all come from these institutions. The optimization metrics could be enhanced with cooperation from cities, to understand how to provide metrics for success that would be convincing to adopt policies during engagement sessions.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said a cost variable or simulation component should be considered in order to ensure it is a pragmatic approach.

Reviewer 2

The reviewer observed the results of the curb simulations are showing very little differences in traffic impacts for the various scenarios that were modeled. It is a bit unclear if the end product, the dynamic curb zoning application will have much user value if it cannot distinguish between various curb use options.

Reviewer 3

The reviewer remarked the proposed future research at this point is about understanding the potential for impact, and targeting application of the results for transition. Two items may be of interest to the team: 1.) validating changes that took place in a city, using historical and current estimates to show the changes on that city's topology; and 2.) establishing the potential energy payoff as a key metric for success, potentially allowing this as a reason for adoption.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer expressed the project is certainly relevant to VTO, and developing a framework and methods for implementation of a true dynamic curve allocation will assist many jurisdictions in the future. However, the project seems to have several budget implications that should be addressed. It cannot be assumed all jurisdictions will be able to afford and implement something like this. The team should consider how this could be designed in an equitable manner given all the implementation needs for the jurisdictions in the future.

Reviewer 2

The reviewer said the project is very relevant to the VTO EEMS program.

Reviewer 3

The reviewer commented the project contributes to overall VTO subprogram objectives in EEMS due to the joint consideration of both vehicle motion (micro) as well as energy use (macro) considerations.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer noted the project's budget seems to be sufficient at this time. The inclusion of different sized jurisdictions would be important in the future in order to better understand any future challenges (small towns versus Med/large cities). If this comparison is feasible, a larger budget might be needed.

Reviewer 2

The reviewer felt the project has sufficient resources to achieve its milestones in a timely fashion.

Reviewer 3

The reviewer stated the resources for the project are sufficient.

Presentation Number: eems101
Presentation Title: RealSim, An Anything-in-the-loop Platform for Mobility Technologies
Principal Investigator: Dean Deter, Oak Ridge National Laboratory

Presenter

Dean Deter, ORNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

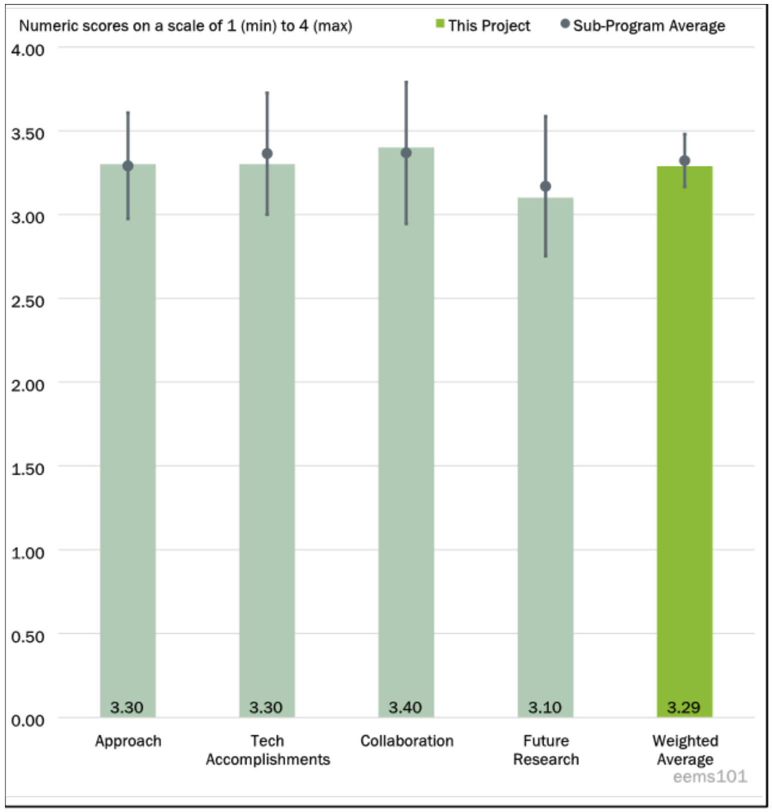

Figure 3-21 - Presentation Number: eems101 Presentation Title: RealSim, An Anything-in-the-loop Platform for Mobility Technologies Principal Investigator: Dean Deter, Oak Ridge National Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer commented the approach addresses the need for realistic simulation of connected and automated vehicle environments and applications. The barriers include the lack of standard tools and the computational requirements needed to develop simulated environments. The project is focused on overcoming these barriers, but the complexity of the simulated environment is still very challenging.

Reviewer 2

The reviewer noted the team has developed a sound approach to addressing this challenge by integrating sensors in the XIL and virtual environment 2.0, creating digital twins using the Real-Sim platform and validating the above using current on-road data from other EEMS projects.

Reviewer 3

The reviewer stated the overall scope of the project is to address the barriers of: 1.) modeling and simulation environment lack of inclusions for all scenarios, 2.) lack of standard co-simulation tools or hooks across vehicle and traffic environments, and 3.) computational requirements of complex environment simulation. Each of these seem well in line with several critical barriers related to the EEMS program. While quite a bit of the work is geared towards capabilities development, these capabilities are somewhat limited in the current research environment. It is not entirely clear how “all” scenarios will be addressed by the current research efforts without an incredibly large data storage and testing infrastructure, but the current effort does appear to provide some much-needed supplementary data. Future presentations could benefit from some specific priority examples where the developed data-streams would help infill current data gaps. Some of these items might be out-of-scope from the existing budget, so it is understandable why certain more complex systems have been left to future/proposed work. Combining a real signal controller into the virtual environment is also a strong benefit to this work as it makes the transfer and applicability of DOE developed strategies very clear in terms of ultimate implementation and possible real-hardware limitations. While certainly known to the authors, this work will likely be increasingly difficult as more complex and integrated systems are developed, making emulation much more difficult. Although challenging, this work appears to provide a foundation from which to continue to expand and develop these techniques.

Reviewer 4

The reviewer observed the approach appears appropriately designed and is intended to be integrated or integral to other EEMS projects and outcomes. The development of the digital twin around real world traffic infrastructures looks to be a major component.

Reviewer 5

The reviewer perceived this project as an extension of the capability of VPPG by integrating more sensors modeling and digital twin elements. The proposed system architecture makes sense. Considering the complexity of the whole real-sim system, it is suggested that the research team better define the scope of the research and ensure the tasks can be completed within the timeline.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer remarked the project has accomplished much related to sensor integration on the vehicle side and signal phase and timing and traffic control integration on the infrastructure side. The vehicle and infrastructure components have undergone initial testing including digital twin data collection in Kane County, Illinois.

Reviewer 2

The reviewer found the team has achieved full emulation of camera/radar/lidar, XIL integration of traffic control devices, confirmation of APaCK-v and -i, and data collection for Randal Road.

Reviewer 3

The reviewer mentioned the project has shown strong accomplishments across the testing and emulation infrastructure required to perform a range of topics and validation experiments. While not totally clear, it is assumed that these capabilities will be adequate for the Task 3 objectives mentioned later in the presentation. Barriers related to computational expense appear to be partly addressed at this point since simulations are operational; however, it appears more insights to the specific balance of computational power versus expense and research value could be a supplementary task within this project. The inclusion of multiple microsimulation programs is a particular strength to these efforts as this ability will likely aid multiple researchers by allowing for an otherwise consistent testing interface and procedures. While still preliminary, it would also be helpful in future presentations to better detail some of the specific validation needs from Task 3 such that a mapping of capabilities and priorities to specific validation outcomes could be readily available. Overall, strong technical progress has been made, with execution building in the later stages of the project.

Reviewer 4

The reviewer stated the ability to perform virtual perception using methods aligned with how real perception hardware (laser imaging, detection, and ranging [LiDAR], radar, camera, etc.) work and function is key to the whole CAV ViL approach. The team has demonstrated that virtual sensors can behave and perform just like real sensors. A big question is how does the "noise" or "jittering" of the (LiDAR) or radar outputs look in the virtual environment. Can imperfect perception signals be replicated?

The hardware stack build-up in the vehicle for perception and data collection is a pretty time consuming task.

Reviewer 5

The reviewer commented that considering the potential impacts from the pandemic, project progress (40%) makes sense. Increased efforts for the rest of tasks are expected to ensure the completion of the planned project. Also, it is a bit confusing about what "multi-layer digital twin" means in this project. Does it refer to "traffic layer" (traffic signal control in SUMO) and "application layer" (physical traffic signal controller)? It

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer observed the project requires collaboration and coordination across multiple EEMS projects whose applications will be testing under the simulation/digital twin environment. The ORNL team is partnered with ANL to accomplish the development of the simulation environment.

Reviewer 2

The reviewer said the team has shown good collaboration with other EEMS projects, ACM, and IPG.

Reviewer 3

The reviewer remarked the project shows strong collaboration across labs and with additional software vendors and testing facilities. Although mentioned in the comments, it is worth mentioning that connecting with an OEM for not only the validation of the specific projects, but also the testing/emulation capabilities would be beneficial. This may provide some perspective on how OEMs anticipate testing these systems in the future and highlight the crossover research as well as gaps where DOE capabilities could supplement industry efforts. It would also be interesting to see if any industry standards bodies or test procedure development groups could benefit from these research insights, so this type of collaboration is suggested as well.

Reviewer 4

The reviewer noted the project team is well coordinated with other national labs and EEMS projects and previous project outcomes.

Reviewer 5

The reviewer asserted it is good to know that both ORNL and ANL collaborate with each other in the project, which can well leverage resources from both laboratories. The inclusion of ACM and other stakeholders would definitely help move the project forward. As pointed out by the PI, the coordination of HiL testing seems to be a major hurdle, which requires attention across different project teams.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer observed the project has identified next steps for sensor integration and development of additional digital twin locations to support selected EEMS projects. This will be a very valuable tool for evaluating EEMS project applications under a variety of simulated scenarios.

Reviewer 2

The reviewer stated the proposed future work involving switching to OPS-CAR (ORNL Platform for Sensor and Control) factory radar sensor, developing traffic control stacks covering 6-8 intersections, completing digital twins, inertial measurement unit (IMU) emulation, establishing computational limits, and verification testing, are all well-motivated.

Reviewer 3

The reviewer felt the near-term future work has been detailed clearly, but later stages of the validation work are less clear. Specifically, some examples of DOE strategies to be validated and how they are supported by the developed experimental infrastructure would be helpful to better understand the overall scope of the future work. An indication of work additional to the proposed scope would also be insightful. For instance, does the research team expect to add more sensor technologies to the emulation or data collection platforms in the future, or would the majority of future work simply relate to executing the current system across a range of validation experiments? A deeper dive into the tradeoffs of data-structures and resolutions needed to emulate higher fidelity sensors would also be suggested as this might help prioritize the computational burden highlighted in the challenges section.

Reviewer 4

The reviewer expressed that switching sensors, namely radar, and changing out IMU is not a direct 1:1 swap. There will be a debugging phase that hopefully does not over consume the team's efforts. The C-V2x hardware seems like an interesting point to expand upon details for the future given that DSRC appears nearly dead.

Reviewer 5

The reviewer commented that it is not very clear about the specific and descriptive to-do list for Task 2 and Task 3. It seems to be a bit dynamic. Therefore, it is a bit difficult to judge how likely these tasks or targets will be accomplished.

Question 5: Relevance: Does the project support the overall VTO subprogram objectives?

Reviewer 1

The reviewer said this project is very relevant to the EEMS program and provides a tool/mechanism for other EEMS projects to evaluate their proposed applications in a simulated/digital twin environment.

Reviewer 2

The reviewer remarked the project supports the VTO subprogram's objectives of developing tools and hardware to model vehicle/traffic scenarios to work towards minimizing transportation energy consumption.

Reviewer 3

The reviewer stated the work matches well with the objectives of the VTO EEMS program. Specifically, the integration of both on- and off-vehicle sensing is well suited to the overall scope and goals of the EEMS program. The project also seeks to provide real-world experimental platforms, data, and validation, which is key to the ultimate success and integration of DOE developed insights and technology concepts.

Reviewer 4

The reviewer mentioned the project is most relevant in developing and validating the virtual perception tools that are a further enabler to CAV ViL/XiL. The project integrates or relates to a number of other EEMS projects and will only help to accelerate the market introduction of the technologies for safety and energy reduction.

Reviewer 5

The reviewer noted the project is definitely related to the VTO subprogram objectives, especially EEMS. The development of mixed reality modeling/testing platforms is a cost-effective way to evaluate CAV technologies.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated the resources appear adequate to complete the project. If issues arise with funding or with complexity of the future development, an option would be to add funds or limit the number or scope of the digital twin experiments that will occur. However, it is unclear how much this would negatively impact the other EEMS projects preparing to test in the digital twin environment being developed under this project.

Reviewer 2

The approved budget of 3.58M for 3 years is appropriate.

Reviewer 3

The reviewer commented the resources appear sufficient for the current scope and baseline hardware creation, but may need to be increased as the project progresses into later testing stages and more complex hardware and software capabilities are needed. As mentioned by the presenters, the computational challenges related to this project are expected to grow as higher resolution sensing begins to be used more frequently. Furthermore, emulating these responses in the virtual environment will likely become more burdensome as well. The Task 3 funding may also need to be reevaluated depending on the scope and difficulties encountered during real-world validation of the proposed methods. In this case, depending on the scale of testing, resources may need to be increased.

Reviewer 4

The reviewer remarked the team is sufficient on resources for hardware, software, sensors and translation of captured data for development of the virtual tools.

Reviewer 5

The reviewer observed the research team can leverage resources from multiple DOE laboratories, testing facilities, software companies, OEMs, and universities, which should be sufficient for the project. However, the HiL testbed resources seem to be critical and competitive across different projects, which needs more attentions.

Presentation Number: eems102
Presentation Title: AI-Engine for Optimizing Integrated Service in Mixed Fleet Transit Operations
Principal Investigator: Philip Pugliese, Go Carta

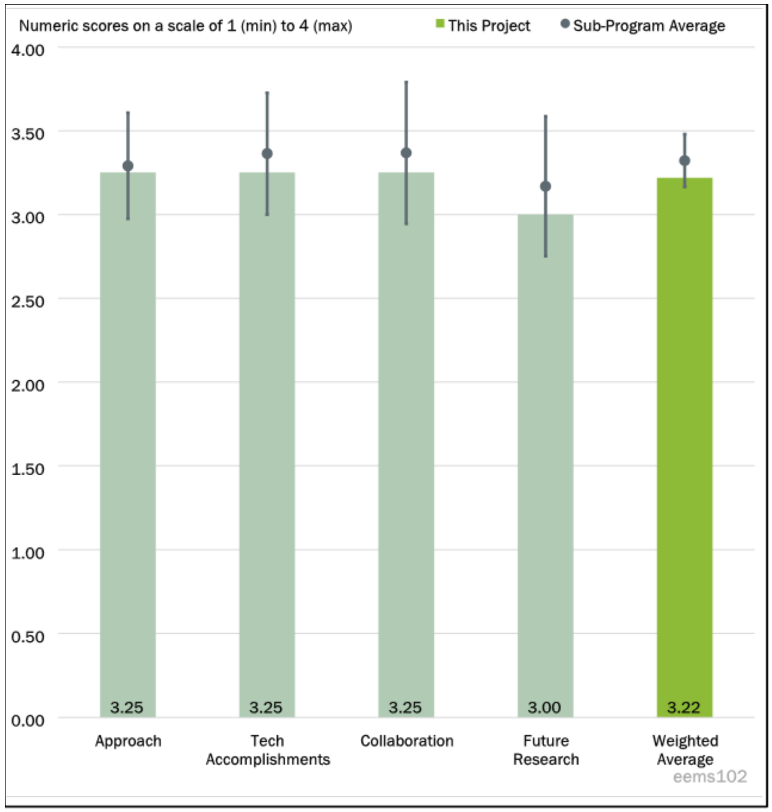

Figure 3-22 - Presentation Number: eems102 Presentation Title: AI-Engine for Optimizing Integrated Service in Mixed Fleet Transit Operations Principal Investigator: Philip Pugliese, Go Carta

Presenter

Philip Pugliese, Go Carta

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer expressed the approach to increasing user accessibility seems good, but integration of fixed and dynamic services is not clear from the presentation given the focus to date on paratransit (presumably, point-to-point service). The Integrated System Concept (Slide 16) shows three systems tied together to an unstated end. Neighborhood microtransit and shared mobility modes are mentioned, but their integration with fixed route services was not. How the community engagement task might induce non-transit users to adopt lower-energy modes is also unclear. Further, project objectives include 10% reduction in total energy consumed. If this is for transit energy use only, it may conflict with the objective to increase trips served by transit.

Reviewer 2

The reviewer noted the timeline showing 45% compete indicates that the integration of so many analytical and simulation tools has been very effectively accomplished, considering how difficult this is to achieve. The noted "sparsity" of trip requests could prove to be a limitation from the data source, although the smaller size of the CARTA transit system is understood to be advantageous during the development of the complex AI engine. The resulting tools would best be ultimately tested (possibly as an extension of this project) under the auspices of this research team and R&D regiment using a larger transit system to assess the efficiency of the AI engine use for larger fleets and trip-request demand patterns. This would also afford an evaluation of the frequency of real-time trip requests, i.e., a more challenging dynamic vehicle routing problem.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer said the presentation does not include a project plan to compare progress against. There has been good progress on discrete elements, especially paratransit optimization and the fleet electrification grid impact analysis. Important elements that are yet to be done include integration of the full multimodal system and interventions to promote adoption of new travel options.

Reviewer 2

The reviewer stated the complexity of developing, refining, integrating and testing so many parts of the comprehensive AI functional plan is acknowledged, and considered in this assessment. The technical white papers prepared to date are noted and give evidence of the AI functional parts being developed. The challenge of completing the deployment and testing, refinement, and validation of the multi-faceted software tools in the remaining two year time-frame appears to be fully capable of being accomplished. Optimization of the battery electric bus fleet deployment and operating schedule is still a major hurdle to clear. The AI engine should be capable of analyzing fleet size considerations combined with the analysis and balancing of the timing throughout the day of high power-demand rate charging cycles, as compared to the alternative strategy of more frequent, lower power-demand charging cycles. This should be part of the ultimate AI engine capabilities.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer remarked the specific roles for all members of the core team are identified, including industry, national labs, universities, and a transit agency. The three entities listed under “community coordination” are not community organizations, so additional effort is warranted to ensure that there is adequate community input, e.g., from underserved populations.

Reviewer 2

The reviewer acknowledged the challenge of coordinating so many players in the algorithm and software development process. With a schedule showing 45% complete, it shows that collaboration and coordination across the team is going well. Elevating CARTA’s interest in real-time, on-demand neighborhood circulator service for first mile/last mile (FM/LM) connections to fixed route transit would significantly enhance the applicability of the AI engine for future AV fleet applications. This collaborative aspect with CARTA to accomplish the real-time, on-demand circulator application should be considered for the final stage of work, even if time and resources only allow the accomplishment of a future research project definition, and a determination of the necessary additional data collection that would be required.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer stated the purpose of most pending accomplishments is clear. The likelihood of success in “algorithmic integration with fixed-line vehicles” as it relates to microtransit is unclear, as work to date has focused on paratransit. The nature of the community “intervention strategies” is not explained, so likelihood of success cannot be evaluated.

Reviewer 2

The reviewer stated the plan for future research that is defined for this project's remaining duration is good, but it would be very advantageous to also address the desire of CARTA to apply the tools beyond current paratransit service application to include neighborhood on-demand circulator applications.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer felt the project aims to maximize efficiency of transit services and increase use of energy efficient modes support the EEMS objective to increase mobility energy productivity.

Reviewer 2

The reviewer remarked AI engine development through this research project is highly relevant to the task of advancing public transit services in the coming age of electrified, automated transit vehicle fleet operations. The project work aligns well with the fulfillment of the VTO EEMS goal for AI applications to "recognize patterns and extract actionable information to answer transportation-related questions through predictive data analytics." The AI engine application is well suited to optimizing the transit fleet operations, minimizing energy use and related costs, and increasing the level-of-service provided to transit riders (including aspects of their behavioral response to alternative services).

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said there is no evidence of insufficient resources for the project.

Reviewer 2

The reviewer stated the basics of the AI engine development, testing and refinement should be able to be completed within the remaining time in the project schedule.

Presentation Number: eems103
Presentation Title: Transit-Centric Smart Mobility System for High-Growth Urban Activity Centers: Improving Energy Efficiency through Machine Learning
Principal Investigator: Jinhua Zhao, Massachusetts Institute of Technology

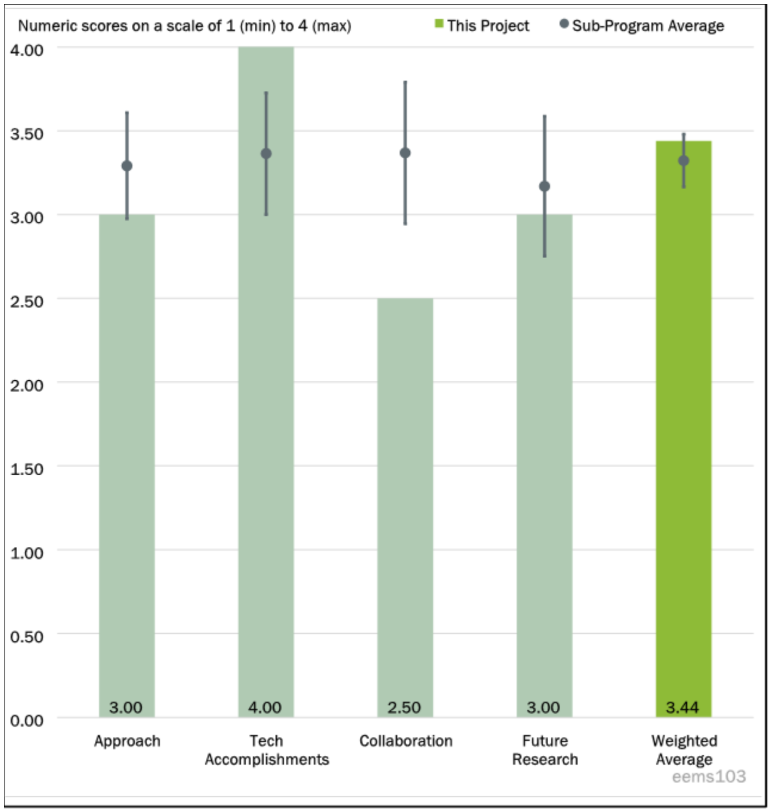

Figure 3-23 - Presentation Number: eems103 Presentation Title: Transit-Centric Smart Mobility System for High-Growth Urban Activity Centers: Improving Energy Efficiency through Machine Learning Principal Investigator: Jinhua Zhao, Massachusetts Institute of Technology

Presenter

Jinhua Zhao, Massachusetts Institute of Technology

Reviewer Sample Size

A total of one reviewer evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer commented the explanation of the relationship between the barriers identified and the approach taken is clear. However, the approach is highly theoretical, and whether it would go far to address Barrier 3 ("transit system is underdeveloped to meet the soaring demand of high-growth urban areas") is not obvious. The proposed 5% improvement in transit level of service and mode share does not seem adequate to address this barrier. Also, it is not clear what the baseline is for the improvement targets, since the transit service in question seems to be partly or entirely new.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer stated the progress on the project is consistent with the project plan, with all milestones met for the first budget period of the project. The technical modules in some cases substantially overperformed the go/no-go points.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer observed all partners (national labs, university, and transit agencies) are assigned to major tasks, but their contributions are not specified in all cases and their participation to date is unclear.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer remarked the proposed future work makes sense given the project approach. Nothing in the work to date suggests that the proposed work will be unachievable. The nature and success of the “pilot experiments” in the next budget period will be important to the value of the project.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said the project supports the VTO EEMS objective to increase mobility energy productivity for individuals and businesses.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer found no evidence of insufficient resources for the project.

Presentation Number: eems104
Presentation Title: Increasing Affordability, Energy Efficiency, and Ridership of Transit Bus Systems through Large-Scale Electrification
Principal Investigator: Ziqi Song, Utah State University

Presenter

Ziqi Song, Utah State University

Reviewer Sample Size

A total of one reviewer evaluated this project.

Project Relevance and Resources

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

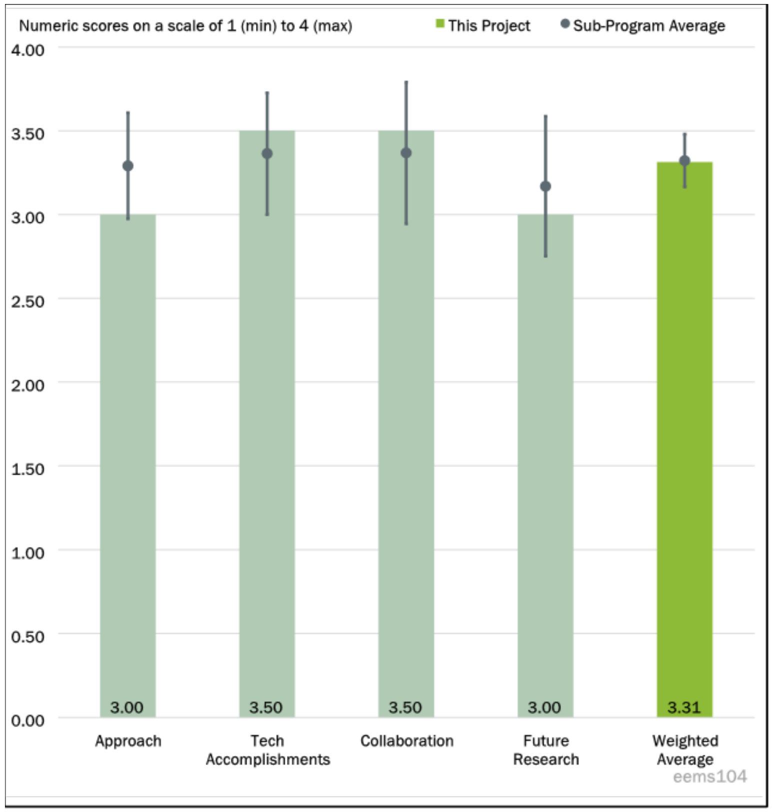

Figure 3-24 - Presentation Number: eems104 Presentation Title: Increasing Affordability, Energy Efficiency, and Ridership of Transit Bus Systems through Large-Scale Electrification Principal Investigator: Ziqi Song, Utah State University

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer commented the project is well-designed to address the need for planning and operations tools for an electric bus fleet. Quantitative objectives for the project are stated in terms of percent cost reduction relative to the non-optimized electric bus case. However, the presenter mentioned that operational costs for electric buses were not proven to be lower than those for conventional buses, which seems like a crucial cost issue to address in the project. The project also aims to increase bus system ridership through electrification. It is unclear how the user surveys will contribute to that result. User views of electric buses, for example, are unlikely to be a primary determinant of ridership. Availability and features of first-mile/last-mile modes would certainly be relevant to ridership, but there is no explanation of what interventions are contemplated around FM/LM modes or how these relate to bus electrification.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer observed the project has reached several milestones as planned and is otherwise generally on schedule, apart from delays due to COVID as noted. The presentation does mention a delay in grid model development and simulation due to electric bus deployment uncertainty. The reason for this and how much of a problem it presents are not explained.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer remarked that partners include national laboratories, universities, a utility, and transportation agencies, all with designated contributions to the project. It is recommended that project researchers communicate with those in the Chattanooga project (EEMS102), which also involves a tool to assess "potential impacts on and constraints of the power grid" from bus fleet electrification.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer stated the purpose of future work is generally well-defined, and the technical work seems feasible based on project accomplishments to date. However the purpose of the survey work is not entirely clear, as discussed above. The presentation notes diminished transit ridership and low response rates to the survey, presumably due to COVID. Continuing low ridership would work against the project goal of improved efficiency and effectiveness of bus systems and aggravate the uncertainty around electric bus deployment.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer commented the project supports the VTO EEMS' objective to increase mobility energy productivity by promoting the adoption of electric buses and improving bus system efficiency. However, challenges to transit systems nationwide due to COVID may call for a rethinking of how transit service can best contribute to this objective.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said there is no evidence of insufficient resources for the project.

Presentation Number: eems105
Presentation Title: Energy Optimization of Light and Heavy Duty Vehicle Cohorts of Mixed Connectivity: Automation and Propulsion System Capabilities via Meshed Vehicle-to-Vehicle (V2V)- Vehicle-to-Infrastructure (V2I) and Expanded Data Sharing
Principal Investigator: Darrell Robinette, Michigan Technological University

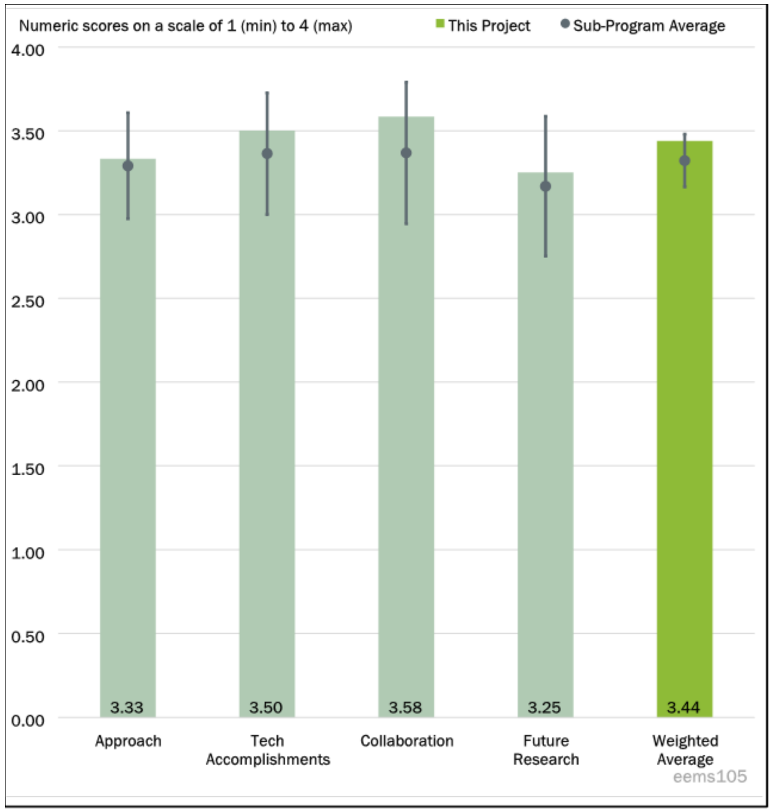

Figure 3-25 - Presentation Number: eems105 Presentation Title: Energy Optimization of Light and Heavy Duty Vehicle Cohorts of Mixed Connectivity: Automation and Propulsion System Capabilities via Meshed Vehicle-to-Vehicle (V2V)- Vehicle-to-Infrastructure (V2I) and Expanded Data Sharing Principal Investigator: Darrell Robinette, Michigan Technological University

Presenter

Darrell Robinette, Michigan Technological University

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer commented the project clearly addresses the stated technical barriers (improving mixed fleet fuel efficiency by using V2X) and does so in a fast-paced, yet rigorous way incrementally using simulation, hardware-in-the-loop (HIL), and road-testing.

Reviewer 2

The reviewer felt the technical approach is sound and the timeline is realistic. Building on other DOE/ U.S. Department of Energy Advanced Research Projects Agency-Energy (ARPA-E) projects is clearly valuable. The wide range of 10%–50% is unsatisfying if a single quantity estimated with such wide spread. But I suspect this is a combination of multiple target/ranges which would be better estimated as separate, tighter bands.

Reviewer 3

The reviewer intimated there are no substantial concerns with the approach to performing the work as written. It is unclear as to what work will be completed. Slides 2 and 7 show work ending in December 2022; however, the slide deck mentions 2023 work. Is the work in FY2023 contractually required? Or is it an option for DOE to consider? This project seems similar to FHWA's Traffic Optimization for Signalized Corridors (TOSCo) project. It is encouraged the team look for opportunities to leverage what's already been completed by that project: https://rosap.ntl.bts.gov/view/dot/50741; and https://www.campllc.org/traffic-optimization-for-signalized-corridors-tosco-phase-2-build-and-test/.

One thing not considered is background traffic. Are the energy savings only for the vehicle in the cohort or is it for the entire system? Unconnected background traffic, either interfering with the cohort's ability to following the recommended trajectories, or following fuel inefficient trajectories behind the cohort (stop and go), may detract from overall fuel consumption savings. FHWA did some initial work in this space through its study of queue-aware signalized intersection approach and departure: https://journals.sagepub.com/doi/full/10.1177/0361198118793001.

This project would also benefit from clarity on language. While the DOE AMR has a structured presentation and limited time, really specific terminology is important for this project since it's introducing a new concept with the idea of cohorts.

Reviewer 4

The reviewer noted the approach seems good, but there are concerns about work remaining in the calendar year and the source data for simulations being unclear/undefined. It seems the bulk of simulation and physical testing is to be completed this year after AMR, and that is a significant amount of valuable work. It would be good to more clearly state where simulation assumptions come from—is the Class 8 tractor in the cohort fully loaded, partially loaded or empty? Is a full mix of vehicle weights being considered to determine the acceleration and deceleration capabilities of the "cohorts' slowest vehicle". The assumptions feeding into the HD tractor performance are critical to the simulation results coming out of this work and as such should be clearly defined (as well as the other vehicles when a Class 8 tractor is not part of the cohort). Additionally, how is the cohort test duration defined and is there any assumptions about cohort duration as a % of overall drive cycle considered? A 20% savings may be significant if it is on a significant percentage of the drive cycle—but insignificant if it is only on less than 1% of the total driving.

Reviewer 5

The reviewer stated that overall, the project approach seems strong. The overall project team contains a wide mix of expertise and the project proposes a range of simulation and real-world experiments that should provide robust and interesting data and insights. The focus on real-time strategy implementations is much appreciated as the project is clearly focused on creating and evaluating strategies that can be implemented in real-world vehicles.

Reviewer 6

The reviewer observed the project explores how to examine connectivity as it can be used in conjunction with automation and real-time technology for energy savings in mixed-vehicle traffic. Mixed-vehicle corresponds to varying levels of automation within the flow.

Fundamentally the project aims to answer the question: can connectivity + automation reduce energy consumption? Most would probably answer this question "Yes" even without research, but as a starting point for exploring how much impact, it is a way to motivate the work. In fact the presenter mentioned between 10-50% improvement, which is an aggressive goal that may be too bold, but would be welcomed if it can be achieved. The approach is to look at situations of signalized intersections, arterial corridors, highway driving, and changes to an integrated drive cycles.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer commented the project has demonstrated significant progress towards its goal of creating a centralized controller to govern the behavior of mixed fleet cohorts to avoid traffic stops by leveraging connectivity. The AI_spd optimization algorithm seeks to ride the "green wave" using a different optimization approach than others in the VTO EEMS portfolio. In the last six months, the algorithm has significantly improved its ability to predict signal timing even for intersections with adaptive signals. The team has prudently employed extensive simulation testing (1,000s of runs) in the project's Design of Experiments to show 19% energy savings in simulation. Results have been partially validated via track test. The project has also demonstrated that cloud latencies (250 msec) are likely acceptable for energy-efficient CDA applications. It is unclear if the 2Hz broadcasted data content uses (or could use) any standard SAE messages. If it does, this could accelerate experimental deployments.

Reviewer 2

The reviewer confirmed progress appears to be well on track. The ability to communicate and process in the cloud is encouraging for future technologies.

Reviewer 3

The reviewer stated the team has handled delays related to COVID well and are on track to finish the project on time according to what was presented at AMR.

Reviewer 4

The reviewer mentioned milestone due dates were not provided in the slides, but assuming the dates given for completion were on time, the project is on track. The project plan does seem back loaded, but that was addressed in the previous question.

Reviewer 5

The reviewer observed that while quite a bit of progress has been made to the overall development and infrastructure needed for testing and evaluation, it appears that quite a bit of experimental testing and analysis is still slated for testing given the 70% completion of the original project timeline. That said, progress seems reasonable given the scope of the project as well as expected delays due to the issues highlighted in the appendix. The design of experiments approach is much appreciated for the arterial work. Some additional high-level insights from the overall study would be greatly appreciated to better understand the energy savings distributions and possibly highlight high-impact considerations and scenarios. It would be helpful to identify the current status to the expected benefits shown in the introductory table. It is not clear where the progress stands for each sub-test and result. Another suggestion would perhaps be to identify a few real-world combination cycles to give an overall improvement for the suite of technologies used across a range of real world driving conditions (as opposed to a focus on specific maneuvers such as approach/departure).

Reviewer 6

The reviewer commented the project has had deliverable results along the following axes: application of powertrain models across the vehicle fleet; production of a simulation environment configurable by acquired data and simulated signaling intersections; platoon optimization techniques based on coordination with infrastructure; simulation baselines against which to compare simulated results; and simulations in various scenarios (arterial for one). The project's technical results strongly match what is proposed, and some of the initial results indicate the potential to (in some cases) meet the high bar for energy savings when compared against selfish approaches. Initial demonstrations are ensuring that the teams understand connectivity dropouts to be taken into account during validation approaches.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer noted each organization has meaningfully contributed critical pieces to the overall project to produce a well-integrated and cohesive product.

Reviewer 2

The reviewer said the team includes a broad range of experts and appears well coordinated.

Reviewer 3

The reviewer observed coordination within the project team is strong. However, there are not many OEMs included on the project team. What's the plan for engaging with OEMs and trying to make the case to get this fuel saving algorithm implemented on production vehicles? Getting the OEMs on board is an underappreciated task and this project would significantly benefit from more OEM involvement in future years. FHWA used the CAMP Consortium as a way to get OEMs involved on TOSCo testing and prototyping.

Reviewer 4

The reviewer remarked coordination is not directly addressed in the slides, but based on progress and responsibilities from different partners collaboration seems to be working. It would be helpful to acknowledge which partners are doing the work on the progress slides.

Reviewer 5

The reviewer maintained the project team is very strong with a mix of industry and academic partners. Overall, the different project contributors are very impressive and should help project execution as well as contributing knowledge to a large range of stakeholders.

Reviewer 6

The reviewer commented the American Center for Mobility provides access to their closed test track facility. AVL Powertrain provides insights into the system of systems simulation environment, simulation, optimization, and CAV drive quality evaluation. BorgWarner provides insights into light duty vehicle-powertrain models and optimization methods. Navistar is an OEM partner for heavy duty vehicles, and Traffic Technology Services provides access traffic signal information. The collaboration across partners is strong, and each partner has insights and expertise that make them a critical partner.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer stated the future research plan for FY23 is a logical extension of work performed and is very likely to meet its targets given the amount of incremental testing done to date. There could be a greater emphasis on exploring how results could be deployed more widely.

Reviewer 2

The reviewer observed the proposed work is internally consistent with project objectives.

Reviewer 3

The reviewer noted there are no concerns with the future research as described (although it is confusing as to what future work is in scope, as mentioned in Q2). It is recommended the future research include a partnership with OEMs and research that looks at the impact of background traffic on the algorithm (and the impact of algorithm plus background traffic) on total energy savings.

Reviewer 4

The reviewer expressed the future research proposed seems to have a clearly defined purpose and seems critical. As previously mentioned, the physical testing seems significant in relation to the time left on the project. As such the targets are aggressive, as vehicle testing often has setbacks. Hopefully, the team can accomplish this because correlating physical test results to simulation is critical to the project's value.

Reviewer 5

The reviewer noted the future project work process steps are identified and it appears that continued progress will be made towards overall project goals. Additional details provided in the supplemental materials are appreciated for a more detailed overview of the on-going developments. Barriers appear to be adequately addresses, but any new insights found during real-world and track testing would be helpful for additional future directions once testing has been completed.

Reviewer 6

The reviewer stated the remaining proposed work is focused the amount of data exchange that is required, and the horizon required for optimization. One technical barrier is in synchronizing among vehicles; this is a somewhat critical concern to understand the constraints, as it may be that the available technology cannot meet constraints. What is the time requirement you need to meet, and how do you plan to mitigate risks if you cannot meet that?

*Question 5: **Relevance: Does the project support the overall VTO subprogram objectives?***

Reviewer 1

The reviewer commented the project demonstrates how connectivity-enhanced automation can decrease energy use of mixed-fleet cohorts and therefore meets VTO EEMS objectives.

Reviewer 2

The reviewer noted that demonstrating mechanisms for coordinated vehicle control to pass through lights is directly consistent with VTO and EEMS program objectives. TTS is a good partner and a potential commercialization path.

Reviewer 3

The reviewer observed "the VTO created the Energy EEMS Program to understand the range of mobility futures that could result from disruptive transportation technologies and services and to create solutions that improve mobility energy productivity MEP, or energy efficiency, affordability, and access provided by the transportation system," as noted on the DOE website link. This project contributes to the EEMS mission by developing new algorithms/methods to reduce energy consumption by leveraging two types of future disruptive transportation technologies (connectivity and automation). Thus, this project supports EEMS objectives. The project contributes to EEMS Strategic Goal #2: Identify and support early-stage R&D to develop innovative technologies that enable energy efficient future mobility systems.

Reviewer 4

The reviewer remarked the project is relevant to multiple VTO objectives. But the relevance is tied to impressive simulation and AI work being tethered to realistic input assumptions and physical testing correlation.

Reviewer 5

The reviewer found a strong connection to VTO EEMS goals, particularly the focus on mixed traffic flows as well as a mix of different real-world scenarios and implementation conditions.

Reviewer 6

The reviewer said the project is relevant to VTO EEMS priorities.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer confirmed the project has demonstrated potentially significant energy savings in relatively little time, so it appears to be well-staffed and well-resourced.

Reviewer 2

The reviewer commented the resources seem appropriate for the project plan and schedule.

Reviewer 3

The reviewer affirmed the project resources seem commensurate with the output of the project.

Reviewer 4

The reviewer mentioned significant funding was allocated to accomplish the goals set out and should be adequate. There is some concern that not enough funding has been saved to complete the remaining tasks.

Reviewer 5

The reviewer stated the resources seem adequate alongside the contributions of numerous project partners.

Reviewer 6

The reviewer noted the resources are sufficient.

Presentation Number: eems106
Presentation Title: Developing an Energy-Conscious Traffic Signal Control System for Optimized Fuel Consumption in Connected Vehicle Environments
Principal Investigator: Mina Sartipi, University of Tennessee

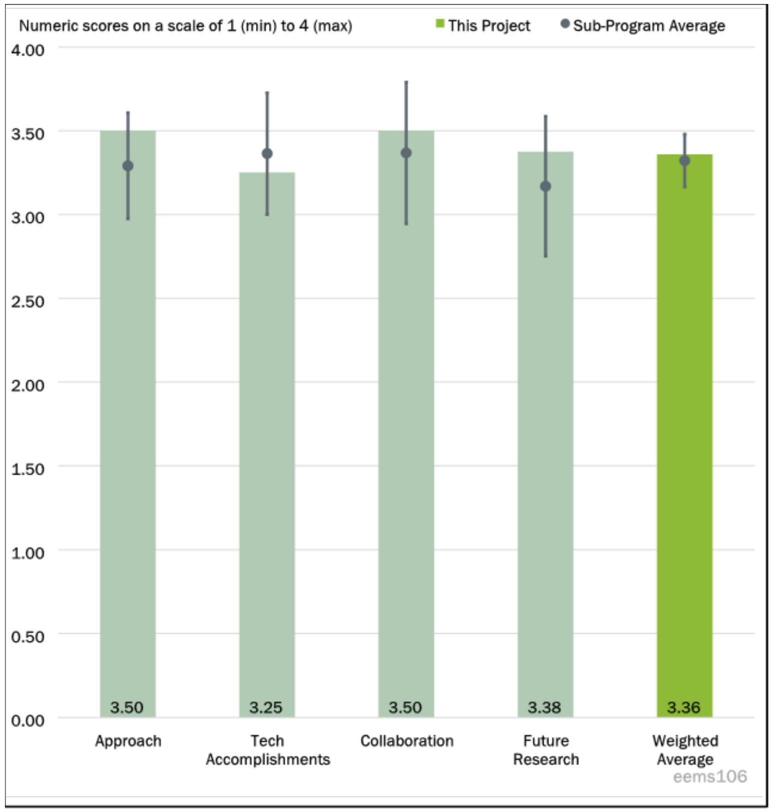

Figure 3-26 - Presentation Number: eems106 Presentation Title: Developing an Energy-Conscious Traffic Signal Control System for Optimized Fuel Consumption in Connected Vehicle Environments Principal Investigator: Mina Sartipi, University of Tennessee

Presenter

Mina Sartipi, University of Tennessee

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer stated the project appears to be on track for FY22. The FY23 transition from simulation to real world demonstration in a year is an ambitious goal and should be closely monitored. Several other projects began their hardware instrumentation and integration work in parallel with algorithm development to mitigate the integration risks, but this one is just beginning to work on hardware.

Reviewer 2

The reviewer commented the approach seems good for this stage of the project. It is unclear about Eco-PI, fuel consumption, GHG and other emissions, as well as time delay in terms of what is being optimized. Additional time delay is not expected, if the traffic flow is the same or better. Additional localized emissions from idling at a stop is definitely a different perspective than fuel-consumption alone. GHG is a global cost, but nitrogen oxides is an example of a more acute local cost when considering local populations. That is interesting to consider, especially in non-attainment zones. But even in attainment zones, micro-locations are adversely impacted by many cars idling. Properly maintained ICE vehicles with warmed-up aftertreatment systems emit almost nothing, But much the overall vehicle fleet is older and emit significantly. The approach from model and algorithm to CAVE HIL lab and then the street is appropriate.

Reviewer 3

The reviewer noted there are no major concerns with the proposed approach. he proposed solution will not require significant infrastructure investments to legacy systems for deployment. This will eliminate many barriers for implementation in the longer term.

Reviewer 4

The reviewer commented that overall program goals and objectives are well thought out, organized and planned, and would make a significant contribution to the field.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer observed that the number of technical approaches has been reduced to a more manageable set of two. (Previously, there had been roughly three approaches considered, each for local and global optimization. This could have given rise to an unruly number of local/global combinations to evaluate.) The approaches (game theory and reinforcement learning) are also consistent across the local/global optimization process, which should hopefully make for a more seamless integration than a mix-and-match approach. This project has made significant progress towards its goals of developing energy-efficient signal control using a variety of technical approaches. Simulation results show promising energy savings, decreased stop delay, and decreased queue length. It is unclear whether/how the controller algorithms address multi-modal priorities.

Reviewer 2

The reviewer said the 40% completion seems a bit behind plan, but perhaps the author is being too conservative in self-assessment. The examples shown appear to represent good progress.

Reviewer 3

The reviewer mentioned that based on Slide 4, there are no concerns with technical progress that has been made compared to the project plan. According to the PI, the project schedule is on target, with no major technical barriers expected to impede anticipated project schedule completion.

Reviewer 4

The reviewer remarked the technical accomplishments are on track and task progress shown. One item was not clear on the integrated HIL and high-fidelity fuel consumption estimation capabilities in simulation. Is this the purpose of the CAVE lab and if so, how is this done? Use of the ECO-PI metric is not clear. How many vehicle classes, propulsion options are considered? The effective weighting is also not clear on time versus fuel consumption. Further, why partition fuel consumption into A, D, and I and normalize to FCi/T? Is fuel consumption (FC) the sustainability metric and time (T) the mobility metric? How are GHG emissions evaluated?

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer noted the project features strong collaborations across the partnering universities; each is contributing a critical piece of the total effort.

Reviewer 2

The reviewer commented a variety of institutions and experts are involved and appear to be well coordinated. Additional powertrain and emissions experts along with health/environmental expertise may be helpful from a consulting perspective, if budget allows, or for future work. Ecological Performance Index (Eco-PI) optimization target trade-offs such as criteria emissions versus fuel consumption (which is mostly the same as GHG emissions).

Reviewer 3

The reviewer noted that based on the presentation, it appears that there is great collaboration within the project team listed on Slide 20. It may make sense to consider adding additional MPOs/local agencies to a stakeholder engagement group just to ensure that the ecological adaptive traffic control system (Eco ATCS) is of interest to other agencies and will work based on their legacy systems hardware and architecture.

Reviewer 4

The reviewer said the team is extensive with relative expertise and resources between partners.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer noted real-world integration may be a considerable challenge. It is unclear how the City of Chattanooga will vet the simulation results before greenlighting the real-world demonstration on the MLK corridor. The PIs spent considerable effort developing EcoPI for their optimization efforts, and it is quite independent of the controllers developed here. EEMS may be interested in consider EcoPI as another performance metric they can evaluate going forward, in addition to MEP.

Reviewer 2

The reviewer confirmed the planned work is internally consistent with the project objectives.

Reviewer 3

The reviewer stated the proposed future research listed on Slide 22 seems logical and reasonable given the time horizon left on the project. As mentioned above, there are no technical concerns with the development of the Eco-ATCS algorithm or deployment on the Smart Corridor to test real world benefits. However, the project may benefit from additional engagement with local agencies that will (hopefully) be deploying the Eco ATCS algorithm just to make sure there are no gaps or concerns as the owners and operators of the legacy systems.

Reviewer 4

The reviewer observed the simulation and field validation will provide significant outcomes matching the goal of the overall program.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer noted this project is focused on improving transportation system-level energy-efficiency by optimizing traffic signal timing, which supports VTO EEMS goals.

Reviewer 2

The reviewer said coordination of traffic systems and vehicles (connected or not) is directly supportive of VTO and EEMS objectives. Demonstrating potential savings will help spur adoption and funding of technologies.

Reviewer 3

The reviewer remarked the project supports EEMS strategic goal #2: Identify and support early-stage R&D to develop innovative technologies that enable energy efficient future mobility systems. A huge benefit of this project is that the Eco-ATCS can operate with data that is obtainable from legacy systems. That could make this project an early win because it is easily deployable.

Reviewer 4

The reviewer commented improvement at the corridor level of mobility and energy reductions for urban environments is an important contribution to the VTO EEMS program objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated the project has made significant progress towards its technical objectives on schedule, so it appears resources are sufficient.

Reviewer 2

The reviewer noted funding resources border on light, but are sufficient for the stated objectives.

Reviewer 3

The reviewer confirmed project resources seem commensurate with the output of the project.

Reviewer 4

The reviewer said resources are appropriate for the project.

Presentation Number: eems107
Presentation Title: Improving network-wide fuel economy and enabling traffic signal optimization using infrastructure and vehicle-based sensing and connectivity
Principal Investigator: Joshua Bittle, University of Alabama

Presenter

Joshua Bittle, University of Alabama

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 17% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

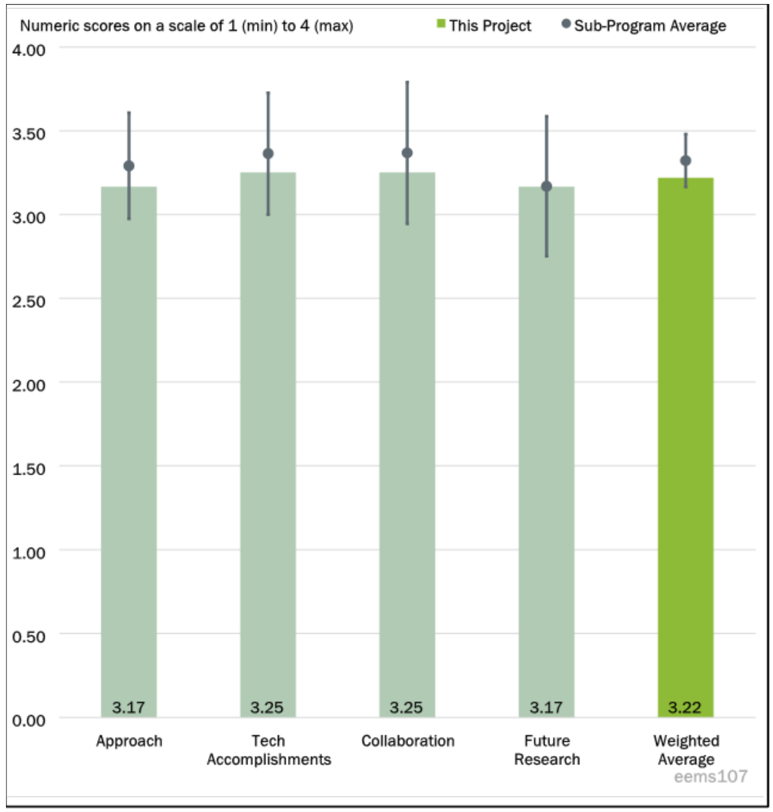

Figure 3-27 - Presentation Number: eems107 Presentation Title: Improving network-wide fuel economy and enabling traffic signal optimization using infrastructure and vehicle-based sensing and connectivity Principal Investigator: Joshua Bittle, University of Alabama

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer noted the project directly addresses the stated technical barriers of quantifying energy savings from the use of AI/ML and CAVs to improve traffic management. The project is well-designed (though rather conservatively scoped—only three intersections with a relatively traditional technical approach) to achieve its stated goals.

Reviewer 2

The reviewer stated the technical approach from intersection up-fit to algorithm, modeling, hardware and road validation is good. The timeline is longer than most at 4 years, but it is unclear if there was some delay. The overall objectives are reasonable and achievable with 20% being a good stretch goal.

Reviewer 3

The reviewer observed the project team is doing a good job of addressing technical barriers with this work. The use of the updated Traffic Analysis Toolbox (TAT) Volume III for the calibration of the microsimulation network is appreciated. One caution is that FHWA found in a recent project (https://www.fhwa.dot.gov/publications/research/operations/21071/index.cfm) that models can be well calibrated according to TAT Volume III recommendations, but the simulated trajectories may still not match real world trajectories. It does not appear the team is using the simulated trajectories as inputs to future calculations (e.g., using simulated trajectories as inputs to Surrogate Safety Assessment Model (SSAM) or MOVES to look at safety or environmental performance metrics), but the issue is raised as a general caution. If the team is, then try to make sure the trajectories are also used as part of the calibration of the traffic simulation model.

Also, are the optimized trajectories broadcast to connected and automated vehicles or connected human driven vehicles? The probe vehicles are L2, but the presentation seems to emphasize the importance of connectivity, not necessarily automation. If the focus is on connected human drivers, how is the team planning on overcoming issues related to driver compliance (i.e., not following the suggested trajectories) and the potential impacts on the system performance? Regardless of which system (e.g., CAV, human driven vehicle) the algorithm is going to be deployed on, how does the team plan on handling interference with optimized trajectories from other vehicles in the traffic stream (e.g., the algorithm says to decelerate at X m/s^2, but the vehicle cannot due to safety issues with the leading vehicle)?

Reviewer 4

The reviewer stated the vehicle and infrastructure instrumentation is clear and moving ahead within the scope of the approach. The co-optimization method of traffic signal and vehicle optimization was not presented so the approach is not clear. Is there a vehicle demonstration on road in the corridor or are the results to be simulation- or CAVE lab-based?

Reviewer 5

The reviewer noted that the overall project approach seems strong. The vehicle instrumentation selected appears well suited to the data collection needs (i.e., AVL fuel scale). Vehicle detection methods and integration platform seems well suited to overall project objectives and progress seems adequate for Year 1 progress. The timeline seems reasonable despite some hardware-based delays. One area for improvement would be to better highlight the anticipated vehicle-level controls that will be developed in later years of the project. The strong use of both real-world, HiL, and simulation testing is likely to provide a set of robust and validated data. The statement “Future Looking Integration of vehicles and traffic control system through C-V2X/DSRC/ V2N at various penetration levels can enable gains now rather than waiting (algorithms will be the same regardless of data source)” is well said. The emphasis on developing algorithms that can utilize multiple data sources is strongly aligned with overall VTO EEMS goals. One suggestion might be to better define the accuracy and detection capabilities at a generic level so different technologies can be identified/refined to meet the general requirements for these types of systems.

Reviewer 6

The reviewer observed the project is jointly considering the infrastructure required, as well as how information can be shared from vehicles, in order to optimize traffic for reduction of energy use. The approach is to deploy infrastructure sensors such as radar, camera, and radios, for awareness of the flow of vehicles. Similarly, vehicles are outfitted with DSRC radios in order to communicate with the infrastructure regarding their own state. The technical barriers are to estimate energy and emissions in future mobility scenarios, quantify the benefits of active traffic management with (and without) connected vehicles, and to explore how AI-related tools are able to aid in this optimization.

The project and timeline are reasonably planned, though one technical barrier highlighted is with regards to connecting to vehicle control for validation. This may be coming too late in the timeline, and the team recognized that there were challenges with respect to the approach. How will this risk be mitigated?

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer noted this project has made significant progress, particularly in its hardware readiness. Its V2X radio testing has been the most thorough of any effort within the current EEMS portfolio, which is why it was presented to USDOT ITS JPO and the SMART Mobility Consortium. Likewise, the infrastructure and probe vehicle sensor installation and characterization have been very methodical. * Energy savings will also be systematically quantified by both repeatable HWIL runs in the ORNL CAVE Lab as well as on-road demonstrations. The approach utilizes very high fidelity representations of both existing and proposed traffic management systems, which may make for a smoother transition to potential wider-spread real world deployment. This is especially true given Alabama DOT has more than 85 instrumented intersections, and this project leverages only 3. There has not been a strong technical focus on algorithm development yet in the project. Despite the fact that algorithms are the greatest source of potential innovation and energy savings, it remains unclear what traditional or AI/ML techniques will be investigated. To date, most of the effort has been focused on the more straightforward components and tasks required to build the ITS system.

Reviewer 2

The reviewer said progress to date appears good, against the plan.

Reviewer 3

The reviewer praised the work to integrate National Electrical Manufacturers Association (NEMA) into SUMO and thanked the team for sharing it openly for others to use. The team is not reporting any concerns with delay to schedule, outside of the radar technical issues (which seems to be resolved). The project seems to be on-track for on time completion and there are no concerns with project progress.

Reviewer 4

The reviewer stated progress on the vehicle and infrastructure activities is clear, but accomplishments for optimization is not clear. How is sensor fusioning being used within the construct of the project? Also, it is not clear what estimates these produce and who consumes them?

Reviewer 5

The reviewer commented the Year 1 milestones and objectives seem to be on track, despite delays related to hardware. The project team seems to have recovered well due to equipment delays and building process flows for analysis and detection. NEMA style dual-ring controller implementation and integration into SUMO alongside publication and release is promising and a strong contribution to the overall user community. DSRC testing looks complete and well done although it appears that some near-corridor areas have limited connectivity (perhaps due to line-of-sight issues). While the vehicle camera detection methods discussion is helpful, it might be useful to highlight an expected level of performance needed for adequate performance as well as any current commercial system capabilities as a point of comparison for the developed methods (i.e., are they a significant improvement or are the existing methods already adequate?).

Reviewer 6

The reviewer observed that ongoing work has demonstrated a clear ability to configure simulation engines such as Sumo with data from the intelligent sensing intersections. The traffic model and V2X testing were critical pieces to the project, and they have been successfully completed. The probe vehicle sensing capacity is also complete, and was a critical piece. While the smart intersections have missed one piece of their technical deliverable, it was due to challenges in hardware from a supplier that are being reconciled following pandemic-influenced supply chain issues.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer noted the project team has a strong collaboration across the university departments, though not as demonstrably strong a relationship outside of the University of Alabama. Very encouragingly, it also has very strong support from Alabama (AL) DOT, with which it regularly coordinates to install and calibrate new instrumentation.

Reviewer 2

The reviewer observed collaboration with Mercedes-Benz, ALDOT and ORNL are good. If Mercedes-Benz is not willing to share the CAN/ECU details needed then the team should consider asking other research groups for help. There is a lot of CAN reverse engineering that happens for DOE, ARPA-E, EPA, etc. Even if the databases cannot be shared, the know-how can help jump ahead to the solutions.

Reviewer 3

The reviewer stated there is strong support across the project team. he involvement of ALDOT is appreciated, including concerns about deployment onto legacy hardware. The team is encouraged to keep looking for opportunities to engage with OEMs (if the optimized algorithm is intended to go onto automated vehicles). The team may also want to engage with other state and local agencies (infrastructure owners and operators) to make sure a wide set of real world deployment issues are being addressed.

Reviewer 4

The reviewer said coordination with ORNL is moving forward for HIL testing.

Reviewer 5

The reviewer stated the project highlights a strong set of collaborators both within the project lead (University of Alabama) as well as other project contributors. ORNL roles are clear as discussed at this point since Year 2 and Year 3 has more HiL and related simulation. The mentioned connection to ALDOT is emphasized as a strong positive and, if possible, would be strengthened to enable more information transfer and real-world insight to be transferred to/from the project teams.

Reviewer 6

The reviewer noted collaboration with ORNL will provide the access to close the loop with the vehicle for integration testing. This is a critical partnership, and the results of the project will depend on ensuring that the hardware-in-the-loop can be achieved in order to do validation testing.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer noted FY22 and FY23 work remain focused on integration efforts. It remains to be seen what innovative control algorithms will help meet the 20% energy savings target; simulation with more traditional approaches has yielded roughly only 10% thus far. The presentation slides hint that tighter alignment with a specific OEM may be needed to leverage vehicle sensor data. This would make scalability much more difficult across multiple OEMs.

Reviewer 2

The reviewer said proposed research is internally consistent with overall project objectives.

Reviewer 3

The reviewer commented future work presented on Slide 7 and 22 is well defined and has a clear purpose. The team is encouraged to think about how background traffic may interfere with the system wide fuel saving potential.

Reviewer 4

The reviewer stated additional details on co-optimization methods are needed to assess effectively.

Reviewer 5

The reviewer observed the project is in its first year, so future work seems acceptably tied into overall project objectives. The translation from 10% go/no-go targets to an overall improvement of 20% is not entirely clear, but significant research time still exists for project execution and refinement. Demonstration with ALDOT is an excellent Year 3 objective as outreach and understanding at the DOT level is critical to real-world implementation and development of EEMS systems. While not discussed in the current scope, it may be helpful to try and identify any off-corridor changes in traffic due to the implementation of the corridor optimization methods, but this may require more sensing than allocated within the project. It is always of interest to make sure additional issues are not created (or are at least made apparent) when new controls are implemented. A possible connection to other EEMS experimental projects may be relevant here as well, for example the EEMS101 data collection systems and vehicles.

Reviewer 6

The reviewer stated the proposed work for the remainder of FY22 is to continue to collect data for system parameterization, and to perform hardware in the loop testing. The FY23 work (if approved) would be to validate the savings in real-world testing, assuming that vehicle control can be achieved. Thus, the connection to be able to close the loop with the car is a critical milestone to be met or mitigated.

Question 5: Relevance: Does the project support the overall VTO subprogram objectives?

Reviewer 1

The reviewer remarked this project is clearly aligned with VTO EEMS goals via the USDRIVE analysis roadmap, which it directly cites.

Reviewer 2

The reviewer stated demonstrating that infrastructure improvements combined with shared information enabling reduced energy consumption is directly aligned with VTO objectives. This approach is similar but different than other ongoing work, and will provide additional insight.

Reviewer 3

The reviewer cited "VTO created the EEMS Program to understand the range of mobility futures that could result from disruptive transportation technologies and services and to create solutions that improve mobility energy productivity (MEP), or energy efficiency, affordability, and access provided by the transportation system.", as stated on DOE's website link. This project looks at the ability on connectivity (and automation?) at improving energy usage. Additionally, this project contributes to EEMS strategic goals 1 and 2.

Reviewer 4

The reviewer noted co-optimization in urban corridors of energy and mobility is relevant to DOE EEMS program.

Reviewer 5

The reviewer observed the project is highly relevant to EEMS goals and highlights the need for improved vehicle detection and control at both the vehicle and infrastructure levels. Detection infrastructure and algorithms are also helpful to assist in the ability to detect traffic flows and vehicles within the corridor.

Reviewer 6

The reviewer said the project is related to VTO EEMS goals.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer commented the bulk of hardware deployments and characterization are underway, and the project is making good progress towards completion. It appears funding, staffing, and procurement resources are sufficient and appropriate.

Reviewer 2

The reviewer observed the funding over 3 years seems very light, especially when considering hardware costs, and access to CAVE. Perhaps there is a lot of unclaimed cost-share that this project is based upon.

Reviewer 3

The reviewer said resources seem commensurate with the output expected on the project.

Reviewer 4

The reviewer noted the project has several collaborators within the University of Alabama in needed fields.

Reviewer 5

The reviewer stated the project resources appear to be sufficient, although it should be noted that the project team has accomplished quite a bit of hardware integration and development while also building a data and analysis pipeline, which is done well within the timeline and budget provided. Hopefully, the infrastructure systems continue to function as this seems to be the largest slowdown at this point, albeit outside the control of the project team.

Reviewer 6

The contractor said resources for the project are sufficient.

Presentation Number: eems108
Presentation Title: Co-Optimization of Vehicles and Routes
Principal Investigator: Jack Schneider, PACCAR

Presenter

Jack Schneider, PACCAR

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

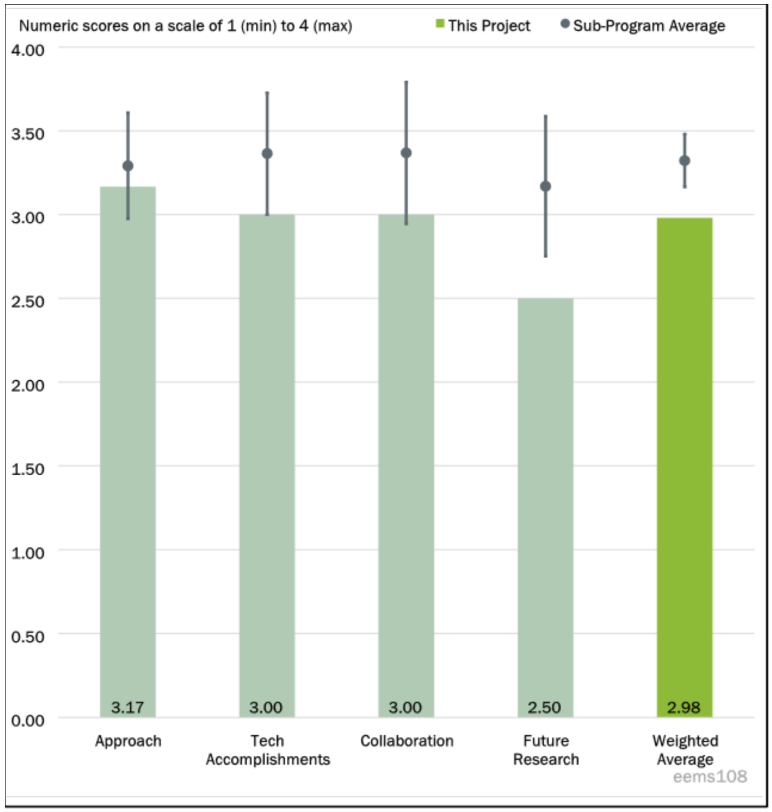

Figure 3-28 - Presentation Number: eems108 Presentation Title: Co-Optimization of Vehicles and Routes Principal Investigator: Jack Schneider, PACCAR

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer stated the project asserts that it will address the barriers associated with business models for these OEMs/fleets. There is not really an attempt to address the commercialization potential of these technologies.

Reviewer 2

The reviewer noted the 25% fleet efficiency goal is stated, but the barriers to achieve it are not evident. The project went through 2 years of simulation, and it appears that there may not be enough time to do the implementation and document the lessons learned.

Reviewer 3

The reviewer commented the project is integrating multiple connectivity features to optimize driver efficiency, eco-routing, powertrain recommendation, telematics and a fleet management system. The first budget period was focused on technology development, the next one is implementing the technology, and the last one will test and validate the technologies developed under the project.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer observed this project asserts that it is about "co-optimization", but how is integrating the powertrain choice into the remainder of the modeling? Co-optimization seems to be a bit of a misnomer here, because the reporting does not really provide a synthesized co-optimization strategy. instead, it offers a serial optimization strategy, without deep interaction and feedback between components. What types of decisions are being made due to powertrain modeling? It appears selections are made from the Paccar catalog, which is not very interesting, optimization-wise. For the EVs, is there more design flexibility, a d can the user consider changes in battery and motor sizing?

Reviewer 2

The reviewer commented nice feasibility analysis from NREL. However, there was not much reported on from Ohio State University. Slide #11 states 2% fleet improvement, but Slide #3 aims at 7%? Valence built a nice dashboard and ESRI the data pipeline. Both depict some initial results, which were also seen from the last year.

Reviewer 3

The reviewer indicated good progress has been made on all tasks. A fleet partner has been identified and committed (which caused some initial delays). Telematics hardware and architecture has been finalized. Routing tools have been integrated and simulations completed. The MATLAB application for powertrain specification optimization has been developed.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer commented that all seems in order from a collaboration perspective

Reviewer 2

The reviewer noted that the researchers have yet show how it all fits together. Again, timing is expected to be the challenge.

Reviewer 3

The reviewer remarked the project has a well-balanced team led by PACCAR with Kenworth as truck OEM, NREL providing fleet data analytics and route optimization, Ohio State University conducting powertrain configuration optimization, ESRI providing cloud infrastructure and routing, and Valence FMS and IDAS; all partners are leveraging their core technology competencies to address the identified project barriers.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer observed the absence of strong documentation on the future research and the program’s commitment and planning towards in-practice testing. The timeline asserts that EVs should be deployed in Q3, 2022. The FY23 work plan does not acknowledge fielding of new vehicles? It is not clear that the IDAS system considers or acknowledges that EV management will be different than ICEV management, in terms of charging, etc.

Reviewer 2

The reviewer pointed out that the project is still at the beginning (after nearly 2 years). However, the reviewer expressed doubt regarding the future work achieving project targets.

Reviewer 3

The reviewer expressed very appropriate future work in FY22 deploying all hardware on 75-80 trucks followed by FY23 testing and validation with planned improvements to ML models. FY23 will also include a workshop with fleet partners on powertrain configuration improvements to disseminate the learnings from the project.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer stated the project is relevant.

Reviewer 2

The reviewer commented this project supports the VTO goals; however, its organization appears to be a bit chaotic.

Reviewer 3

The reviewer said the project is very relevant to the VTO objectives as it targets 25% fleet freight efficiency improvement by developing, implementing, and validating an advanced connected transportation system and is powertrain agnostic. In turn, this efficiency improvement will reduce petroleum use and therefore increase energy security.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer deemed the resources are adequate.

Reviewer 2

The reviewer observed the budget is appropriate. However, there is a timing issue, and an extension may be in order to generate some lessons learned.

Reviewer 3

The reviewer said the overall project budget seems sufficient for the scope that is bringing together several partners and integrating a number of different connectivity systems.

Presentation Number: eems109
Presentation Title: Connected and Learning Based Optimal Freight Management for Efficiency
Principal Investigator: Ali Borhan, Cummins

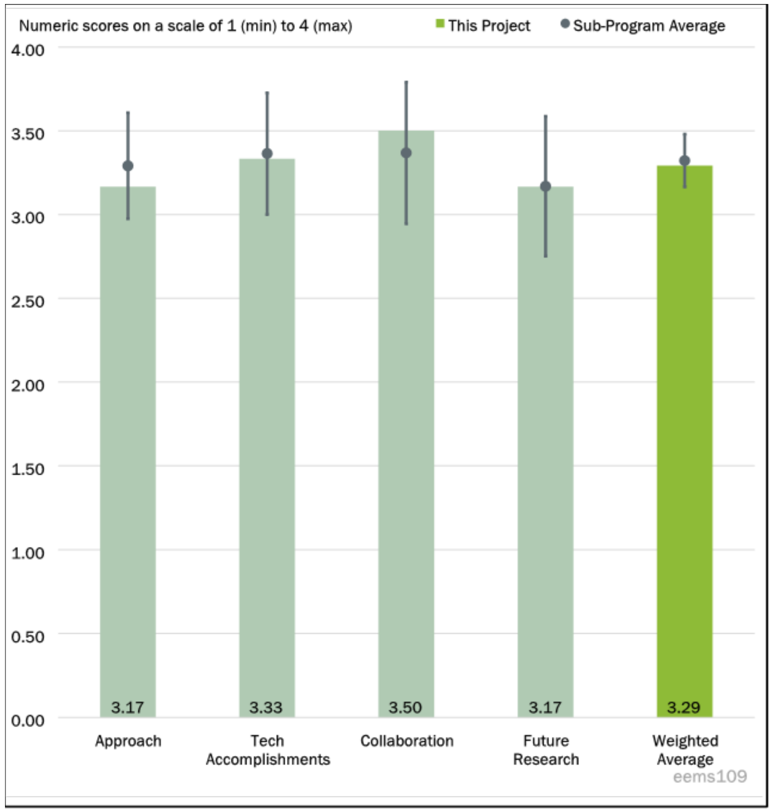

Figure 3-29 - Presentation Number: eems109 Presentation Title: Connected and Learning Based Optimal Freight Management for Efficiency Principal Investigator: Ali Borhan, Cummins

Presenter

Ali Borhan, Cummins

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer commented the reduction in driver wages, and breaking the law in terms of driver operation assumptions (Slide 13) should be reconsidered from an equity lens. It is unclear whether we should be making such inequitable assumptions in a fleet management setting. Fleet management is a multi-disciplinary decision making environment that must consider all stakeholders.

It is also not clear whether the Learning Fleet Optimizer is doing both the "planning" level and "daily" level optimization. The results on Slide 14 talk about seven ICEs and two BEVs as a case; is this the result of previous "planning" level optimization? Why does this project and the optimization model not consider BEV purchase price in determining the number of BEVs that should be in the fleet?

Reviewer 2

The reviewer said the work is nicely organized. It appears to be managed well. The tasks are clear and distributed accordingly.

Reviewer 3

The reviewer stated the project has a good approach using fleet optimizer to provide decision variables for fleet modeling to evaluate well to wheels carbon dioxide impacts while data is being provided back for learning algorithms.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer observed the project seems okay There are many important tasks to be implemented/integrated in 2022.

Reviewer 2

The reviewer remarked the results were presented and the project is starting to bear fruit.

Reviewer 3

The reviewer commented the team has accomplished several milestones including baseline freight system simulation modeling and its validation with fleet operational data. The project is well on the way to demonstrating 20% freight efficiency operation in simulation.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer mentioned tire connectivity is not well integrated to the rest of the project. It is not understood how the tire project connects to the remainder of the project.

Reviewer 2

The reviewer said there is good coordination between the team members.

Reviewer 3

The reviewer expressed the project team is strong including University of California-Berkley (learning algorithms for fleet optimizer), ANL (POLARIS-SVTrip-Autonomie fleet simulation and fleet optimizer integration with POLARIS), Venture Logistics (insights on freight operations and data collection), and Michelin (tire locomotion energy savings). Team members seem to be interacting frequently and appropriately in support of the 3-year project scope with numerous tasks.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer inquired whether the fleet management implementations are going to be implementing the entire suite of technologies? Does this include AVs, advanced powertrains, tires? The speaker asserts that only the fleet management tool will be implemented. It seems there is a lot of uncertainty in operating EVs using the management techniques proposed. There is a lot of uncertainty regarding the feasibility of the AV technologies proposed. One concern is that the results will not demonstrate significant efficiency improvement.

Reviewer 2

The reviewer said the next tasks and challenges are clearly stated.

Reviewer 3

The reviewer stated the proposed future research for budget period 2 to demonstrate the 20% or greater freight operation efficiency in simulation, and budget period 3, to do so with a mix of micro simulation and actual fleet operation, seem logical and appropriate based on the list of upcoming and ongoing subtasks.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said the project is relevant.

Reviewer 2

The reviewer confirmed the project is very relevant to VTO EEMS.

Reviewer 3

The reviewer observed the project is relevant to VTO subprogram objectives as it aims to demonstrate greater than 20% fleet well-to-wheel carbon dioxide reduction over a baseline fleet. This will in turn reduce trucking petroleum use through powertrain and other efficiency improvements.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated the resources are adequate.

Reviewer 2

The reviewer said the project has sufficient funding.

Reviewer 3

The reviewer commented this project seems appropriately funded given the significant scope and partnerships.

Presentation Number: eems110
Presentation Title: Human Factors and Technologies Design to Improve User Acceptance of Pooled Rideshare (PR) for Increasing Transportation System Energy Efficiency
Principal Investigator: Yunyi Jia, Clemson University

Presenter

Yunyi Jia, Clemson University

Reviewer Sample Size

A total four six reviewers evaluated this project.

Project Relevance and Resources

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

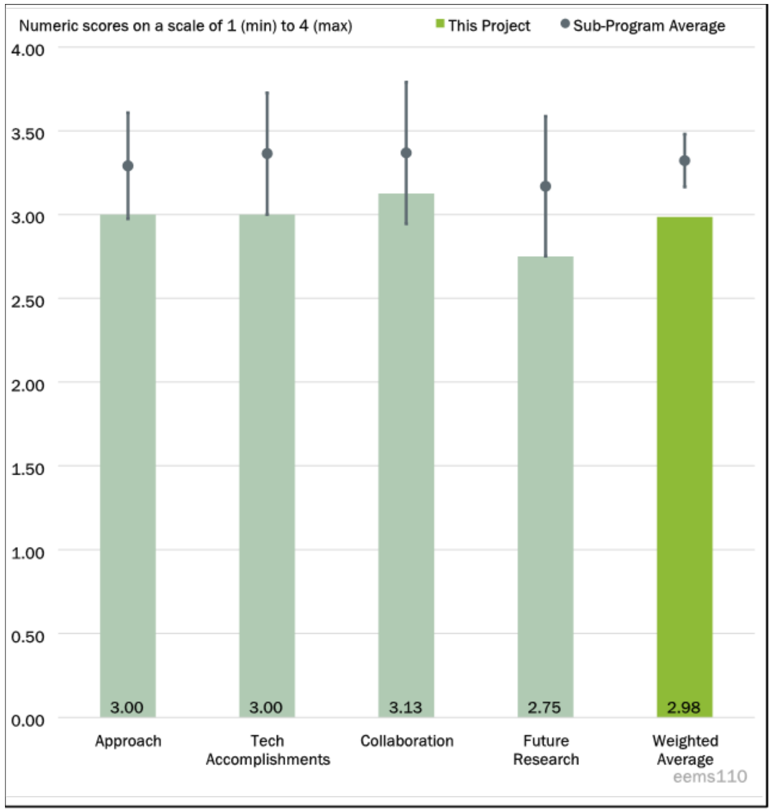

Figure 3-30 - Presentation Number: eems110 Presentation Title: Human Factors and Technologies Design to Improve User Acceptance of Pooled Rideshare (PR) for Increasing Transportation System Energy Efficiency Principal Investigator: Yunyi Jia, Clemson University

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer commented that it is not clear how technology adept the participants are for these Human Factors studies. For these types of studies, balancing based on the type of technological level is important to not skew/bias the results. For example, early technology adopters might be savvier about how to optimize use of these resources than elderly participants that have not owned a computer before. This and other factors could impact their ability to use the system or parts of the system.

Reviewer 2

The reviewer stated the project explores the relationship between human factors elements and acceptance of pooled ridesharing services, taking into account both demographic factors and elements of the service (mode, routing, human-machine interface [HMI], etc.). To this end, they have surveyed travelers and are analyzing reported travel behavior and attitudes. Since this project began in 2020 and data were collected in 2021, sentiment/hesitation related to pooled rideshare may be notably impacted by COVID-19. Having said that, the project design seems thoughtful, and the results will be of interest to MOD stakeholders and others interested in more effectively encouraging use of other shared mobility options, such as transit, in the future. The timelines for proposed research (outlined, for example, on Slide 19) seems reasonable.

Reviewer 3

The reviewer observed an approach that combines an effective public opinion and user choice survey with mode choice models and on-demand ride-share operations modeling is an important milestone toward the preparations for automated mobility systems deployment. With the unforeseeable barrier of the pandemic that affected public attitudes about rideshare options, the survey results provide a measurable benchmark from which the future development of rideshare impacts on mobility can be analyzed. The current attitudinal surveys provide both a "bottom" of the mode choice data, as well as an excellent measure of where R&D investments in vehicle technology and service approach are needed to increase the user choice of ride share transportation. By analyzing the pubic reluctance to ride-share based on key factors, the necessary steps to improving pooled rideshare prospects with future automated technologies can be better understood. However, it is noted that the presenter referenced the extended timeline becoming apparent for advanced vehicle technology deployment, and emphasized that this study's results also have high relevance to existing transportation network companies' (TNC) technology understanding and improvements.

Reviewer 4

The reviewer expressed this is a very strong social science research project. The depth and details of the community outreach is great. The team has plans for further engagement with the community and to understand the needs and reasons for why it is not choosing pooled rideshare.

However, the technical solution is not strong. It is not clear how the team is planning to address the challenge, considering COVID has made pooled rideshare less attractive. Not enough details are provided on what new pooled strategies or technologies will be used to address the challenges discovered through survey data collection. It is not clear how HMIs or multi-mode pooling can help. POLARIS is mentioned to be used for simulating the ridership experiment. It may be also good to consider BEAM (Behavior, Energy, Autonomy, Mobility—Comprehensive Regional Evaluator) as they have studied pooled rideshare and human factors.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer acknowledged that trying to do Human Factors research in the middle of the pandemic was certainly a big challenge for many. Kudos to the team for all they were able to accomplish. Certainly the results might show a bias due to the pandemic, but this is something that we need to account for moving forward since the results are very relevant to the current transportation environment.

Reviewer 2

The reviewer commented there is still significant time left in this project and already the key findings would be of interest to those in the shared-use mobility space. The project seems to be generally on track relative to the project plan, particularly given the challenges associated with trying to conduct this work during an ongoing pandemic.

Reviewer 3

The reviewer observed that based on the core aspect of completing the Task 1 studies on public attitudes on shared mobility, the impact of Covid has significantly delayed the % of project completion. A 30% complete status versus about half of the time passed has been the resulting impact to the progress. There is still time to make up the delays and recover the lagging % complete. The Task 2 and Task 3 work is only now beginning, but that work has multiple partners involved to complete the work.

As a general comment, note that a concise definition is needed for "personal ride-share" vs. " pooled rideshare". Pooled Rideshare is better understood based on Uber-Pool service and similar TNC initiatives. But personal rideshare seems to be a contradiction in terms with no definition in the AMR materials or in the AMR presentation. Also, the acronym "PR" is easily confused with "personal rideshare" rather than the intended "pooled rideshare".

Reviewer 4

The reviewer noted that one of the major concerns from users was trust. It is not clear how the physical design mentioned as part of the solution can help with that. The team has done great work on the social science aspect of the project. The technical job needs more detailed justification on how to address the challenge of user acceptance of pooled rideshare.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer stated the project has great collaboration and partnerships. It seems to highlight the knowledge and expertise of all the partners and focus them in the correct portions of the tasks at hand.

Reviewer 2

The reviewer mentioned the project involves a diverse pool of partners, including Ford and well known transportation research groups. While it is uncertain how specific/distinct roles were divided up to produce the findings laid out in the slides(though some role delineation is laid out on Slide 18), the collaborative effort seems solid based on project progress/achievements this far.

Reviewer 3

The reviewer remarked the 30% project completion with only Task 1 and Task 4 showing progress on the timeline appears to indicate that Tasks 2 and 3 have not yet been fully engaged. Although the two key tasks of Task 2 and Task 3 appear to be where the work is lagging behind, the associated task collaboration and coordination can bear the most fruit in catching up on the % completion. It is noted that the collaboration/coordination between the associated partners may be a challenge that is still to be fully addressed.

Reviewer 4

The reviewer noted that five other EEMS projects are referenced in the presentation and how they can potentially leverage them. POLARIS from ANL will be used in the project.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer expressed that future work was more focused on pending tasks for the project than what should happen after the project is completed.

Reviewer 2

The reviewer comments the proposed future research seems ambitious but interesting, expanding (for instance) to explore additional pooled ride strategies and technologies including adaptive routing and shared AVs. Given the variety of variables, there may be some simulation and validation challenges. However, as outlined, the results once published will be interesting to read. The results will generally hit the targets, and there will be ample opportunities to continue to expand and build upon this work in the future.

Reviewer 3

The reviewer observed the proposed future work comprising Tasks 2, 3 and the remainder of Task 4 is essential for meeting the goals and objectives of the project. Using the survey results and analysis of Phase 1 and Phase 2 data collection, the future work can now be engaged in earnest and the project will thereby achieve its intended objectives.

Reviewer 4

The reviewer commented the challenge of lack of comprehensive understanding of human factors in pooled rideshare is addressed in the current phase. The future work to address the challenge of the pandemic impacting pooled rideshare and how technology can address it is not investigated or planned in detail.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said this is a very timely project. Shared mobility offers possibilities, but without accounting for all the Human Factors aspects it would be hard to optimize it in order to obtain the energy efficiency being sought.

Reviewer 2

The reviewer noted ride-sharing can help to reduce net vehicle miles traveled and emissions. Understanding factors that impact one’s willingness to share rides, therefore, can serve to inform associated planning and service development and help to encourage/support shifts towards more energy efficient travel. As building “an affordable, efficient, safe, and accessible transportation future” is the mission/vision of VTO EEMS, this work supports DOE objectives.

Reviewer 3

The reviewer expressed accurate operational modeling of mobility systems which include ridership levels and patterns, while also deriving metrics that allow capital and operating costs and the associated ridership revenues to be calculated, is very well aligned with the VTO EEMS program objectives. This project addresses this multifaceted modeling requirement, basing it on surveys to obtain a thorough understanding of user choices and the related human factors of ride-share services. This project has a good balance of these aspects and is very important to complete.

Reviewer 4

The reviewer said this project can potentially increase energy efficiency of transportation by increasing the pooled rideshare user acceptance.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated the resources seem reasonable and sufficient.

Reviewer 2

The reviewer commented that while more time and resources could help to further gather data and look at it through different lenses, the resources seamed overall to be sufficient.

Reviewer 3

The reviewer observed the resources to complete the remaining work appear to be sufficient if the cost share for Tasks 2 and 3 and the remainder of Task 4 is about half of the budget allocation.

Reviewer 4

The reviewer said the team has sufficient resources for the project.

Presentation Number: eems111
Presentation Title: Contextual Predictions and Eco Services for Electrified Vehicles
Principal Investigator: Jacopo Guanetti, AV-Connect, Inc.

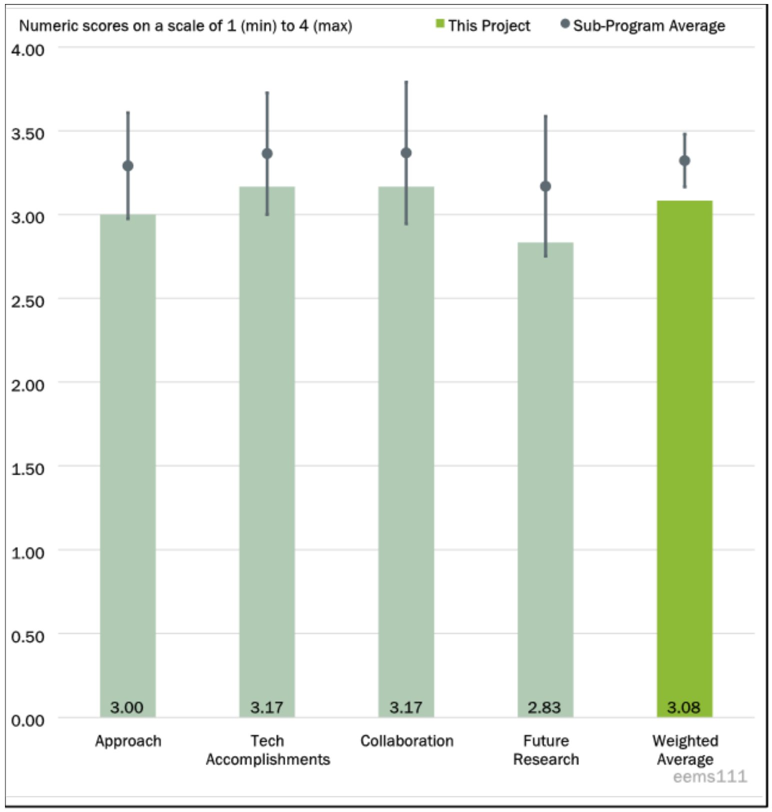

Figure 3-31 - Presentation Number: eems111 Presentation Title: Contextual Predictions and Eco Services for Electrified Vehicles Principal Investigator: Jacopo Guanetti, AV-Connect, Inc.

Presenter

Jacopo Guanetti, AV-Connect, Inc.

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer remarked the technical approach and schedule are sound. The team should be careful with jointly minimizing charging time. Studies are showing that direct-current fast charging for all charging can reduce battery life to 1/3 (a 2/3 reduction). That would impose significant capital and environmental costs for replacing a battery pack. Although a detailed model might not be available, consider a literature review and then a crude model integrated into the cost function. Perhaps certain users just want to minimize charging time, but likely will not require this to always be the case. Fleets may be a different story, and the GHG savings of EVs might be better than the cost of swapping packs. That could be investigated.

Reviewer 2

The reviewer commented it is not clear that the barriers of the project are entirely novel, eco-routing and many of the design elements pointed to in the presentation are present in existing applications (or are actively being pursued). It seems a stretch to claim that eco-routing can lead to higher adoption of electric vehicles: 1.) why would this be exclusive to EVs? and 2.) how many people think about eco-routing when purchasing an EV (and even if they did, it would not be exclusive to the technology). On Slide 6, the team points to several challenges for why the approach is difficult, but it does not seem to me that the work actually addresses any of these problems.

Reviewer 3

The reviewer stated the project aims to overcome barriers of range anxiety for EV drivers, as well as overall energy efficiency of drivers, by suggesting routes that are likely to save energy when compared to the time-optimal route. The results then present the operator with a route that has energy savings, alongside the time/travel difference in taking that route. The Phase I efforts were focused on demonstrating the cloud infrastructure and working with OEMs and partners in order to acquire data and constraints. While the efforts make progress, there are project scope concerns regarding how the project will scale as the number of vehicles that would use this technology would scale. The proposers recognize that there are limits to the side roads that could be used by large portions of the traffic, but this should be quantified so as to understand the technical market cap of using this solution.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer observed that technical progress and milestone accomplishments are on plan. The routing app and multiple driving demonstrations are encouraging.

Reviewer 2

The reviewer asserted progress seems adequate given what is proposed. However, the validation portion of the project with measurement of real world vehicles seems rather limited. With only four EVs, and a planned four EV buses, it is uncertain how a project of this scale can compete against algorithms that learn off much higher volumes of vehicle trip data such as from Google Maps, Waze, Apple Maps, or ABRP.

Reviewer 3

The reviewer noted the project has created models for the vehicle's operation as well as its charging, alongside models and maps for charging stations and types. The technical work in using these strategies is interesting, and especially the mapping that encourages driving styles/distances alongside charging locations. This could help in reducing total cost of ownership by ensuring battery ranges and charging points stay within long-term use guidelines. There are challenges in justifying the behavioral model through Neural Networks, namely that more data will be needed than are perhaps feasible. Why is a neural network approach required, when first order or second order models may be sufficient, and would not require the kinds of data needed to build a model that avoids overfitting?

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer deemed collaboration is good with an OEM (HATCI), a complementary commercial partner and municipalities. The need and opportunity for a fleet customer is correctly recognized.

Reviewer 2

The reviewer stated the collaboration seems reasonable, and the contributions of stakeholders to provide data is fine. The only suggestion is to try to partner with an institution/entity that can provide substantially more data.

Reviewer 3

The reviewer mentioned the project includes partners from Hyundai, NNG, Capital District Transit Authority in Albany New York, and SouthWest transit. While these are provided in the slides, the details of milestones and tasks related to these partners could be strengthened in order to ensure that the engagement is meaningful in the sense that transition of results to practice is more feasible.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer stated the proposed work is internally consistent with project objectives.

Reviewer 2

The reviewer commented the future work is somewhat ambiguous; for data collection efforts, it would be beneficial to provide a better understanding of the scope of data collection. This is an important portion of the project that helps inform calibration and validation tasks. Future work should include plans for increasing stakeholder engagement and expansion of these activities.

Reviewer 3

The reviewer observed the proposed work is largely continuing along existing lines. One item that may be of importance would be to understand how validation tests should be captured/recorded/designed so as to maximize probability of transition of the results. Namely, what is the plan for transition? Is the goal to have algorithms be transitioned to EV OEMs, or be integrated into navigation applications already available? The approach there will dictate what kinds of artifacts from testing would be needed to justify that organization pursuing the technology for transition.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer stated the energy savings objective is clearly aligned with VTO and EEMS objectives. The reviewer further suggested that we are at the beginning of a messy transition to EVs, and that this technology has merit in that it can help ease the transition period.

Reviewer 2

The reviewer commented the project lines up with VTO objectives.

Reviewer 3

The reviewer said the project is relevant to VTO EEMS goals.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer deemed funding seems appropriate for the plan.

Reviewer 2

The reviewer remarked the budget seems to excessively grow between phases. It is uncertain if the effort and outcomes from the second phase warrant a 5-10x increase in budget.

Reviewer 3

The reviewer said the funds are sufficient.

Presentation Number: eems112
Presentation Title: National Renewable Energy Laboratory Core Modeling & Decision Support Capabilities, Route Energy Prediction Model (RouteE), Future Automotive Systems Technology Simulator (FASTSim), OpenPATH, and Transportation Technology Total Cost of Ownership (T3CO)
Principal Investigator: Jeff Gonder, National Renewable Energy Laboratory

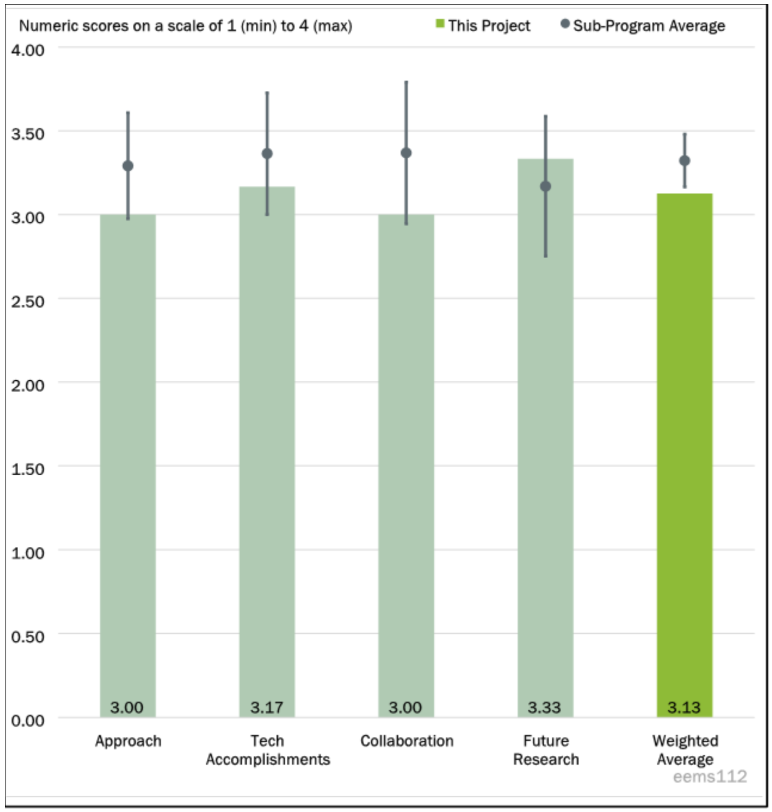

Figure 3-32 - Presentation Number: eems112 Presentation Title: National Renewable Energy Laboratory Core Modeling & Decision Support Capabilities, Route Energy Prediction Model (RouteE), Future Automotive Systems Technology Simulator (FASTSim), OpenPATH, and Transportation Technology Total Cost of Ownership (T3CO) Principal Investigator: Jeff Gonder, National Renewable Energy Laboratory

Presenter

Jeff Gonder, NREL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer observed the technical barriers seemed a bit broad, although this might be reasonable given the breadth of this project and the variety of models that it covers. Nevertheless, it might be helpful to provide a bit more detail on what these impacts might be (costs, emissions, etc.).

Reviewer 2

The reviewer asserted this is a potentially very impactful project. There is high confidence in the team addressing all technical barriers, but the project effectively just started.

Reviewer 3

The reviewer commented the team's approach is good and involves the use of FASTSim for real-world fuel economy modeling, route energy prediction, transportation technology total cost of ownership modeling, and instrumenting human mobility with OpenPATH.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer observed that given the very brief implementation period, the progress described in the presentation is very impressive. There are no directed comments on progress, but the results from the numerous modeling efforts under the umbrella of this project are eagerly awaited until next year's update.

Reviewer 2

The reviewer remarked the project team is effective in overcoming barriers, such as improving models and data availability to support research and development of advanced mobility solutions. Examples of the prior accomplishments are evident in propagation of FastSim to many users globally. The Google decision to employ the project's results to allow Google Map users to make informed decisions about less GHG producing routes is an excellent example of how to achieve high impact quickly and at the same time cope well with high uncertainty and rapid changes in mobility technology and behaviors. The developments of NREL's web-API and smart device app are commendable too.

Reviewer 3

The reviewer said the team has the following significant accomplishments: Numerous EEMS application examples (BEAM CORE, Optimizing regional mobility, big data solutions for Mobility, etc.); broader VTO/DOE applications to decarbonization, energy analytics, and total cost of ownership; industry users including Google Maps, GM, Toyota, and DOE 21st Century Truck Partnership; and other users such as the Colorado Energy Office, etc.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer stated the project clearly demonstrates a wide array of collaborative activities given the scope and breadth of modeling efforts being covered. There are many examples throughout the presentation of engagement with partners and stakeholders. One suggestion would be to improve Slide 21 to explicitly show the connection of each entity with project activities (e.g., X,Y,Z were involved with FastSIM and A,B,C were involved with OpenPATH etc.).

Reviewer 2

While the project team is no stranger to establishing effective collaborations and delivering useful results collaboratively, the reviewer commented that a clearer coordination plan is needed at least for main/primary collaborators. Perhaps, the lack of such a plan is because the project is in its very beginning stages and that FastSim is so popular among many R&D teams, but a clear plan is still recommended.

Reviewer 3

The reviewer said this project involves numerous collaborations across national labs and industry partners/stakeholders.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer stated the description of future work was well done, which included both technical aspects of the modeling but also potential engagement activities that demonstrate alignment with the stated objectives of the project.

Reviewer 2

The reviewer remarked the project is almost all in the future since it has barely started. The examples of implemented results so far suggest that the future goals will be more clearly defined this year and will be refined every year accordingly.

Reviewer 3

The reviewer observed the proposed future work plan includes eco-routing approaches, documentation, vehicle updates, and enhancements to OpenPATH. This plan is well-motivated.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said the project lines up with VTO objectives.

Reviewer 2

The reviewer commented the relevance of this project to the overall VTO subprogram objectives is very clear.

Reviewer 3

The reviewer found the project supports the VTO subprogram’s stated goal of modeling transportation systems with a view to reducing energy use and improving mobility.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated the amount of funding seems reasonable for the scope and size of the project.

Reviewer 2

The reviewer concluded the project has sufficient resources to achieve and even exceed its goals. The project team plans to have extensive outreach to many organizations (albeit with a yet to be clarified plan), and that is the reason the milestones could be exceeded.

Reviewer 3

The reviewer stated the approved budget for 3 years is appropriate.

Acronyms and Abbreviations

ACC	Adaptive cruise control
ACEEE	America Council for an Energy-Efficient Economy
ACM	American Center for Mobility
AMR	Annual Merit Review
ANL	Argonne National Laboratory
ARPA-E	U.S. Department of Energy Advanced Research Projects Agency-Energy
BEAM	Behavior, Energy, Autonomy, and Mobility
BEAM CORE	Behavior, Energy, Autonomy, and Mobility Comprehensive Regional Evaluator
BEV	Battery electric vehicle
CAN	Controlled area network
CARMA	Cooperative automation research mobility applications
CAV	Connected and automated vehicle
CAVE	Connected and Automated Vehicle Environment
CDA	Cooperative driving automation
CMU	Carnegie Mellon University
HDOT	Hawaii Department of Transportation
COVID-19	Coronavirus disease 2019
CRADA	Cooperative research and development agreement
CV2X	Cellular vehicle-to-everything
DOE	U.S. Department of Energy
DOT	[state or city] Department of Transportation
DOT	U.S. Department of Transportation
DSRC	Dedicated short-range communication
Eco ATCS	Ecological Adaptive Traffic Control System
EEMS	Energy Efficient Mobility Systems program
EPA	U.S. Environmental Protection Agency
EV	Electric vehicle
FHWA	Federal Highway Administration
FM/LM	First mile/last mile
FTE	Full-time equivalent
FY	Fiscal Year

GHG	Greenhouse gas
GM	General Motors
HIL	Hardware-in-the-loop
HMI	Human-machine interface
HPC	High-performance computing
IARIA	International Academy, Research and Industry Association
ICE	Internal combustion engine
IIT	Illinois Institute of Technology
IMU	Inertial measurement unit
INEXUS	Individual Experienced Utility-based Synthesis
INL	Idaho National Laboratory
ITS	Intelligent Transportation Systems
JPO	Joint Programs Office
LBNL	Lawrence Berkeley National Laboratory
LiDAR	Laser imaging, detection, and ranging
MEP	Mobility Energy Productivity
ML	Machine learning
MOTION	MObility Technology Interstate Observation Network
MOVES	MOtor Vehicle Emission Simulator
MPO	Metropolitan planning organization
MTU	Michigan Technological University
NEMA	National Electrical Manufacturers Association
NHTSA	National Highway Traffic Safety Administration
NREL	National Renewable Energy Laboratory
ODD	Operational design domain
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PATH	Partners for Advanced Transportation Technology
PHEV	Plug-in hybrid electric vehicle
PI	Principal Investigator
PNNL	Pacific Northwest National Laboratory
POLARIS	Planning and Operations Language for Agent-based Regional Integrated Simulation

R&D	Research and development
RDD&D	Research, development, deployment, and demonstration
SAE	Society of Automotive Engineers
SMART	Systems and Modeling for Accelerated Research in Transportation
SSAM	Surrogate Safety Assessment Model
SUMO	Simulation of Urban MObility
SVTRIP	Stochastic vehicle trip prediction
TAT	Traffic Analysis Toolbox
TNC	Transportation network companies
TNC	Transportation network companies
U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability
UAV	Unmanned aerial vehicle
V2I	Vehicle-to-infrastructure
V2V	Vehicle-to-vehicle
V2X	Vehicle-to-anything
VIL	Vehicle-in-the-loop
VOICES	Virtual Open Innovation Collaborative Environment for Safety
VTO	Vehicle Technologies Office
VTOL	Vertical take-off and landing
XIL	Everything-in-the-loop

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4. Electrification

The Vehicle Technologies Office (VTO) supports research, development, deployment, and demonstration (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. The office's investments leverage the unique capabilities and world-class expertise of the national laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies and systems (including automated and connected vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement); combustion engines to reduce greenhouse gas (GHG) emissions; and technology deployment and integration at the local and state level. In coordination with the other offices across the Office of Energy Efficiency and Renewable Energy (EERE) and the U.S. Department of Energy (DOE), the Vehicle Technologies Office advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

The VTO Electrification Technologies subprogram supports the decarbonization of transportation across all modes, serves to increase American advancement/manufacturing of battery technology, and creates good paying jobs with the free and fair chance to join a union and bargain collectively. The subprogram supports research with partners in academia, national laboratories, and industry covered under the Energy Storage Grand Challenge key priority and distinct crosscuts. The Energy Storage Grand Challenge encompasses research and development (R&D) across electrification including electric vehicle charging infrastructure. The Critical Minerals crosscut aims to realize electric drive motor innovations through high energy product magnet R&D to reduce or eliminate heavy rare earth magnet materials. Grid Modernization continues to develop Smart Charge Management technologies for fleets, including medium and heavy vehicles to provide more advanced grid services such as resilience of the charging network and continuity of grid and emergency services operations during disruptive events.

The Electric Drive R&D activity supports early-stage R&D for extreme high-power density motors that have the potential to enable radical new vehicle architectures by dramatic volume/space reductions and increased durability and reliability. Reduce the cost of electric traction drive through core research of motors, high-density integration technologies, leveraging high performance computing for modeling and optimization, and utilizing new materials for high-density electric motors. Approaches will include novel circuit topologies and new materials for high-density electric motors. Electric traction drive system integration based on electric motor innovations will also be a priority.

The Electrification R&D activity supports early-stage R&D to understand the potential impacts on, and benefits of, plug-in electric vehicle (PEV) charging to the Nation's electric grid. This research will inform the development of communication and cybersecurity protocols; enable industry to enhance the interoperability between charging equipment, the on-board vehicle charger, and charging networks; and foster technology innovations to improve PEV refueling through extreme fast charging. Core research focuses on developing smart charging, extreme fast charging, and wireless charging technologies for reliable and cost-effective charging of light-, medium-, and heavy-duty electric vehicles. This includes the research of technologies related to cybersecurity of electric vehicle charging/supply equipment, and integration with the electric grid.

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
elt094	Development and Demonstration of Medium-and-Heavy-Duty Plug-In Hybrid Work Trucks †	John Petras (Odyne Systems)	4-8	3.50	3.50	3.75	3.75	3.56
elt158	Zero-Emission Cargo Transport II: San Pedro Bay Ports Hybrid & Fuel-Cell Electric Vehicle Project	Seungbum Ha (South Coast Air Quality Management District (SCAQMD))	4-11	3.00	2.88	3.50	3.25	3.03
elt179	Low Cost, High-Performance, Heavy Rare-Earth-Free 3-In-1 Electric Drive Unit	David Crecelius (American Axle & Manufacturing)	4-15	3.43	3.29	3.21	3.36	3.32
elt188	Bi-Directional Wireless Power Flow for Medium-Duty, Vehicle-to-Grid Connectivity	Omer Onar (Oak Ridge National Laboratory)	4-20	3.50	3.33	3.17	3.33	3.35
elt197	High Power and Dynamic Wireless Charging of Electric Vehicles	Veda Galigekere (Oak Ridge National Laboratory)	4-23	3.60	3.50	3.60	3.30	3.51
elt208	Highly Integrated Power Module	Lincoln Xue (Oak Ridge National Laboratory)	4-28	3.60	3.60	3.70	3.30	3.58

elt209	High-Voltage, High-Power Density Traction-Drive Inverter	Gui-Jia Su (Oak Ridge National Laboratory)	4-32	3.60	3.60	3.60	3.50	3.59
elt210	Development of Next-Generation Vertical Gallium-Nitride Devices for High-Power Density Electric Drivetrain	Andrew Binder (Sandia National Laboratories)	4-36	3.38	3.75	3.63	3.25	3.58
elt215	Permanent Magnets Without Critical Rare Earths to Enable Electric Drive Motors with Exceptional Power Density	Iver Anderson (Ames Laboratory)	4-39	3.50	3.33	3.33	3.17	3.35
elt216	Isotropic, Bottom-Up Soft Magnetic Composites for Rotating Machines	Todd Monson (Sandia National Laboratories)	4-42	3.38	3.38	3.38	3.25	3.36
elt217	Integrated/Traction Drive Thermal Management	Bidzina Kekelia (National Renewable Energy Laboratory)	4-46	3.33	3.17	3.83	3.33	3.31
elt218	Advanced Power Electronics Designs-Reliability and Prognostics	Doug DeVoto (National Renewable Energy Laboratory)	4-49	3.50	3.50	3.40	3.50	3.49
elt221	Integrated Electric Drive System	Shajjad Chowdhury (Oak Ridge National Laboratory)	4-53	3.50	3.50	3.10	3.40	3.44

elt236	Direct-Current Conversion Equipment Connected to the Medium-Voltage Grid for Extreme Fast Charging Utilizing Modular and Interoperable Architecture	Watson Collins (EPRI)	4-57	3.50	3.50	3.50	3.00	3.44
elt237	Enablig Extreme Fast Charging with Energy Storage †	Jonathan Kimball (Missouri S&T)	4-59	3.67	3.50	3.67	3.17	3.52
elt238	Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State Direct-Current Protection	Srdjan Lukic (North Carolina State University)	4-62	3.63	3.38	3.00	2.88	3.33
elt239	High-Power Inductive Charging System Development and Integration for Mobility	Omer Onar (Oak Ridge National Laboratory)	4-66	4.00	3.83	3.17	3.50	3.75
elt240	Wireless Extreme Fast Charging for Electric Trucks (WXFC-Trucks)	Mike Masquelier (WAVE)	4-69	3.38	3.25	3.50	3.25	3.31
elt241	High-Efficiency, Medium-Voltage Input, Solid-State, Transformer-Based 400-kilowatt (kW)/1000-V/400-A Extreme Fast Charger for Electric Vehicles	Charles Zhu (Delta Electronics)	4-73	3.67	3.33	3.83	3.33	3.48
elt252	Wound-Field Synchronous Machine-System Integration toward Increased Power Density and Commercialization	Lakshmi Iyer (Magna Services of America Inc)	4-76	2.75	2.75	3.00	3.00	2.81

elt253	Motor with Advanced Concepts for High-Power Density and Integrated Cooling for Efficiency Machine	Jagadeesh Tangudu (United Technologies Research Center)	4-80	2.75	2.50	2.63	2.63	2.59
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)	4-84	3.00	3.00	3.00	3.17	3.02
elt256	Amorphous Metal Ribbons and Metal Amorphous Nanocomposite Materials Enabled High-Power Density Vehicle Motor Applications	Mike McHenry (Carnegie Mellon University)	4-87	2.75	3.25	3.00	3.13	3.08
elt258	Grid-Enhanced, Mobility-Integrated Network Infrastructures for Extreme Fast Charging (GEMINI-XFC)	Andrew Meintz (National Renewable Energy Laboratory)	4-91	2.50	2.50	2.33	2.67	2.50
elt259	Development and Commercialization of Heavy-Duty Battery Electric Trucks Under Diverse Climate Conditions	Marcus Malinosky (Daimler Trucks North America)	4-95	3.38	3.25	3.38	3.33	3.31
elt260	Improving the Freight Productivity of a Heavy-Duty, Battery Electric Truck by Intelligent Energy Management	Teresa Taylor (Volvo)	4-99	3.50	3.50	3.50	3.38	3.48

elt261	High-Efficiency Powertrain for Heavy-Duty Trucks using Silicon Carbide Inverter	Steve Peelman (Ricardo)	4-103	3.33	3.17	3.17	3.50	3.25
elt262	Long-Range, Heavy-Duty Battery-Electric Vehicle with Megawatt Wireless Charging	Stan DeLizo (Kenworth)	4-107	3.00	2.50	3.17	2.67	2.73
elt263	Low-Cost Rare-Earth-Free Electric Drivetrain Enabled by Novel Permanent Magnets, Inverter, Integrated Design and Advanced Thermal Management	Ayman El-Refaie (Marquette)	4-110	3.75	3.50	3.25	3.50	3.53
elt264	Demonstration of Utility Managed Smart Charging For Multiple Benefit Streams	Joe Picarelli (Exelon/Pepco Holdings Inc.)	4-114	3.63	3.38	3.50	3.00	3.41
elt265	A Secure and Resilient Interoperable Smart Charging Management (SCM) Control System Architecture for Electric Vehicle's-At-Scale	Duncan Woodbury (Dream Team LLC)	4-119	2.83	2.33	2.67	2.67	2.54
elt266	Next Generation Profiles: High Power Charging Characterization	Dan Dobrzynski (Argonne National Laboratory)	4-122	3.20	3.60	3.70	3.20	3.46
elt274	eMosaic: Electrification Mosaic Platform for Grid-Informed Smart Charging Management	David Coats (ABB)	4-127	3.17	2.83	3.00	3.17	2.98

elt277	Electric Vehicle Integrated Safety, Intelligence, OperatioNs (eVision)	Madhu Chinthavali (Oak Ridge National Laboratory)	4-130	3.33	3.50	3.33	3.33	3.42
elt278	Electric Vehicles (EVs) at Scale Laboratory Consortium	Andrew Meintz (National Renewable Energy Laboratory)	4-133	3.00	3.20	3.10	3.10	3.13
Overall Average				**3.33**	**3.27**	**3.31**	**3.22**	**3.29**

† Denotes poster presentation.

Presentation Number: elt094
Presentation Title: Development and Demonstration of Medium-and-Heavy-Duty Plug-In Hybrid Work Trucks
Principal Investigator: John Petras, Odyne Systems

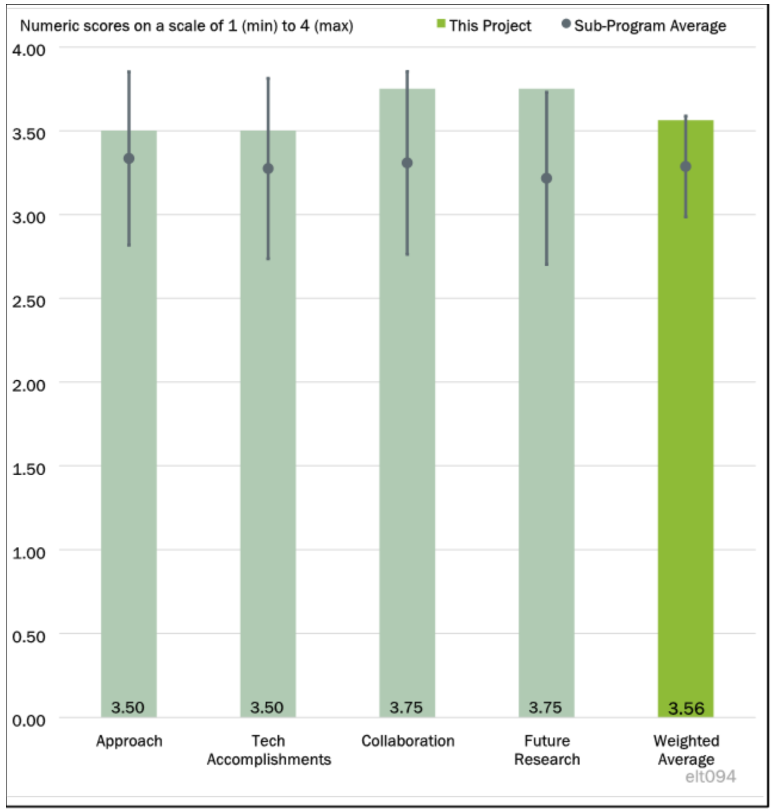

Figure 4-1 - Presentation Number: elt094 Presentation Title: Development and Demonstration of Medium-and-Heavy-Duty Plug-In Hybrid Work Trucks Principal Investigator: John Petras, Odyne Systems

Presenter

John Petras, Odyne Systems

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer identified the following as strengths. The objective of the Odyne project is to develop and demonstrate a modular plug-in hybrid electric vehicle (PHEV) medium-heavy duty work truck system with greater than 50% reduction in fuel consumption when compared to a conventional diesel vehicle baseline. The reviewer said the Odyne project approach is excellent. It incorporates hybrid power through the existing power take-off port, launch assist/regenerative braking while driving, and all-electric application power for stationary work with no changes to the base powertrain. The approach incorporates a three-component modular design which allows installation on most chassis and applications. Options exist for a second battery and exportable power. The reviewer noted that a strong, conventional development approach has been followed: including R&D, test/evaluation, demonstration, and subsequently commercialization. Odyne is working with chassis original equipment manufacturers (OEMs), final stage and equipment manufacturers, and fleet customers to understand the diverse requirements of the work truck market. The reviewer noted that Odyne is working with national labs to analyze the work truck cycle and optimize driving and full day hybrid driving/work strategies, and that efforts continue to lower costs and expand applicability. The reviewer said there were no readily apparent weaknesses.

Reviewer 2

The reviewer said the approach is a clever way to electrify conventional work vehicles when bespoke hybrid powertrains may not be economically viable.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer remarked project goals are substantially on track, with demonstration hardware ready for deployment.

Reviewer 2

The reviewer identified as strengths the project completed technical and design development of the system.

In December 2021 (budget period 2), through dynamometer testing and duty cycle analysis, the team demonstrated greater than 40% improvement in driving fuel economy and predicted greater than 50% reduction in average annual fuel use. For driving fuel economy assessment, the chassis was tested at the National Renewable Energy Laboratory (NREL) with 3 drive cycles for work truck operation and two hybrid on-road drive cycles (mild and aggressive). The mild strategy yielded a 9%-23% improvement in fuel economy, while the aggressive strategy yielded a 69%-75% fuel economy improvement. The stationary work cycle yielded an 80%-99% reduction in fuel use and emissions. The simulated full year fuel savings for the Odyne PHEV Work Truck was 54.6%. The team completed build, delivered demonstration vehicles, and began training / support to demonstration fleet (early 2022). The reviewer identified as a major Accomplishment how this project is indicating commercial success. Three Odyne customers have ordered PHEV vehicles in new Odyne markets including cranes, city refuse, and electrified street sweeper.

The reviewer identified as a weakness how the project mentions continuing efforts to reduce cost, but no specifics are provided.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The project tasks are assigned to different partners according to expertise and the collaboration has achieved the desired results.

Reviewer 2

The reviewer said project is collaboration is outstanding. A broad, diverse set of project participants have been included and deeply integrated throughout the project evolution. This includes national labs (NREL and Oak Ridge National Laboratory [ORNL]), expert powertrain and transmission (Allison) and battery system (Ricardo) firms, a public utility (Tacoma Public Utilities) for demonstration, and project cost share partner (South Coast Air Quality Management District [SCAQMD]). There are no readily apparent gaps nor weaknesses in the project team.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer remarked next steps support and complete the project objectives. Application to all-electric chassis is a bit fuzzy (would seem to be a different project at that point).

Reviewer 2

The reviewer identified as strengths continuing to work with Tacoma Public Utilities to deploy and monitor the demonstration vehicles; collecting insights from operators and fleet managers; completing installation of telematics system, collecting data, and optimizing; and beginning development of next generation work truck system for an all-electric chassis being introduced into the market. The reviewer said that there were no readily apparent weaknesses.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said the project is developing technology that enables electrification of work vehicles. This also furthers the energy efficiency goals of VTO.

Reviewer 2

The reviewer noted that medium- and heavy-duty work trucks consume over 50% of their fuel during stationary jobsite work and idle conditions. Current efficiency and hybridization efforts by large truck manufacturers focus on driving efficiency as opposed to stationary fuel savings opportunities. Odyne has created a modular hybrid electrification system applicable to a large portion of the medium- and heavy-duty truck market that has demonstrated a full duty/driving cycle fuel economy savings of over 50%. The reviewer said this will expand its application opportunities with concomitant energy and environmental benefits.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer remarked resources provided for this project have been sufficient to conduct the scope of project activities. The project incorporated 50% cost share.

Reviewer 2

The reviewer said the project is on track for completion and appears to be sufficiently funded.

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

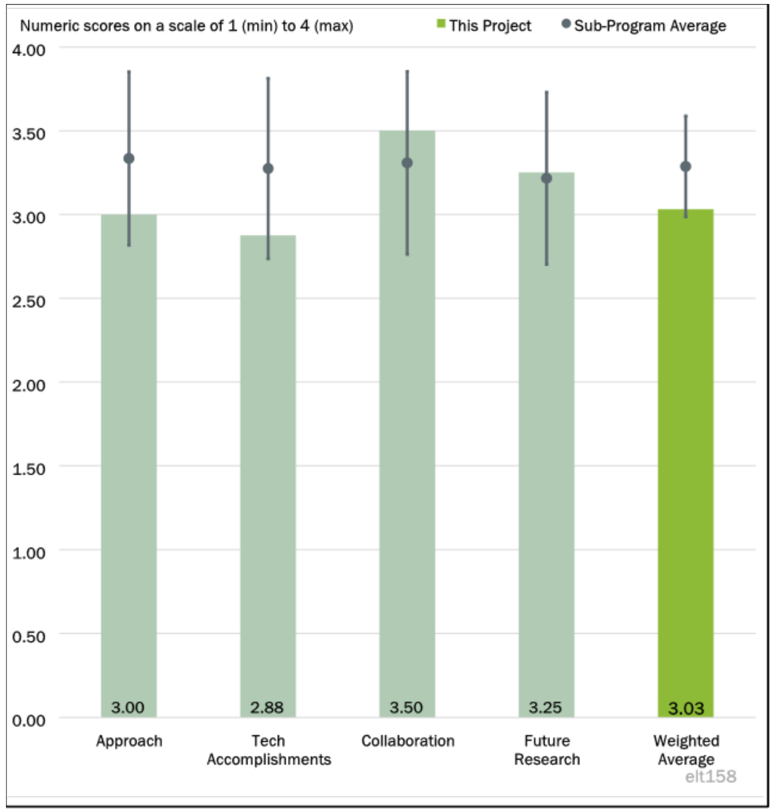

Figure 4-2 - Presentation Number: elt158 Presentation Title: Zero-Emission Cargo Transport II: San Pedro Bay Ports Hybrid & Fuel-Cell Electric Vehicle Project Principal Investigator: Seungbum Ha, South Coast Air Quality Management District

Presenter

Seungbum Ha, SCAQMD

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said the technical barriers are addressed directly and the project is well designed. The timeline is reasonably planned and has adapted appropriately to real-world events.

Reviewer 2

The reviewer remarked the project does a good job at integrating the few fuel cell prototypes currently available into a real work setting to evaluate the benefit of the technology. The team has installed hydrogen fueling stations to support deployment of the vehicles in the field. The documentation of each vehicle's performance is useful as it helps convey what is required to meet the duty cycle.

Reviewer 3

The reviewer is puzzled by five important aspects in the approach to performing the work.

First, the principal investigator indicated that he would complete the development of the Cummins fuel cell truck in 2022. The principal investigator does not present any charts showing that this has been accomplished. This statement was repeated in 2021.

Second, the principal investigator needs to show a milestone chart for each of the five projects listed on Slide 2. The reviewer has no idea of the progress on each project, let alone what are the specific goals for each of the five projects and thus what needs to be accomplished.

Third, Slide 8 seems to show the same data as that which was presented in 2021. There is no need to repeat this data unless a point is being made, and the reviewer does not see the point being made. If the data differs from that presented in 2021, please explain the differences.

Four, Slide 9 shows that the principal investigator understands the difference between battery-dominant and fuel-cell dominant vehicles as each one affects a vehicle's range, but he needs to show how this relates to each of the six projects. For example, is the approach to the development of the truck in project #1 battery-dominant or fuel-cell dominant and why is range important or not important?

Five, the principal investigator needs to do a better job of documenting the causes for the excessive downtime in the fuel cell vehicles under development because they stymie progress as well as demoralize the operators who deploy the vehicles (e.g., comments [from operators] such as "another waste of money and waste of my time!"). The principal investigator should be itemizing the frequency of each component failure or cause of failure.

Reviewer 4

The reviewer noted that this is a very long project, 10 years and questioned whether fuel cells are the focus. The reviewer noted that truck cost and fuel cost H_2 should be included. The reviewer asked is Slide 8 based on range, reliability or otherwise?

The reviewer noted that this is such a long and drawn-out project. The relevance of the technology application naturally changes as the base technology evolves. It was not clear that there was a plan to include technology change from the beginning but instead to just adapt along the way.

The reviewer asked where is the comparison of the many technologies to succeed in operation on a typical route? Need to bring the segments of the project into conclusion and have a summary slide to report on it. The reviewer noted that can be a basis for comparison of next project segments.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer commented the technical progress has been excellent although the execution timeline has been longer than the original plan.

Reviewer 2

The reviewer stated that overall, the team did a good job putting the vehicle to the test. All vehicles met expectations and were very popular with the drivers. All this shows great potential for the technology, which is one of the goals of this project.

This reviewer wished there had been a bit more details and analysis of the powertrain. For instance, how is the fuel cell used, how is power split between the battery and the fuel cell? What are the advantages of having a higher power fuel cell system?

Reviewer 3

The reviewer said Slides 8 and 9 do not offer any quantitatively derived conclusions regarding how the fuel cell trucks performed. Then, the change from fuel cell trucks to a compressed natural gas (CNG) hybrid vehicle just seems to be a scope shift that does not move toward the original intended outcomes of the project. This is not a Zero Emissions Vehicle.

Reviewer 4

The reviewer noted that at least a temporary portable refueling structure has been located and installed. The team completed demonstrations of six trucks and gathered performance data. A roadmap for commercialization has been compiled.

The reviewer found Slide 19 confusing--please explain why only the Kenworth ZECT is shown—is it representative of all the fuel-cell trucks or is it the best-performing of all the fuel-cell trucks?

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer noted this project required a lot of coordination with the OEM who supplied the vehicles, the folks who put the hydrogen infrastructure in place, as well as the folks who did the data collection and analysis. The reviewer said job nicely done.

Reviewer 2

The reviewer remarked as things have moved around in this long-term project, it seems that the team has shifted accordingly. Managing those shifts is not a trivial matter.

Reviewer 3

The reviewer said there is widespread collaboration that crosses over at least seven contractors or organizations, including most importantly, a fleet operator—TTSI, the contractor for temporary refueling station, and the contractor for data collection which makes for a sum total of 10. This extent of collaboration and coordination is quite unusual. TTSI was an excellent choice for a fleet operator.

Reviewer 4

The reviewer commented the collaboration and coordination across the project team has been very effective.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer remarked that the CNG hybrid truck is not a zero emissions vehicle in any sense of the definition.

Reviewer 2

The reviewer is giving the benefit of the doubt to the principal investigator. Even though the principal investigator has not clearly articulated the specific goals/objectives for each of the six projects in the scope of work, he seems to be headed in the right direction and has sufficient insight into the technical barriers/obstacles that must be overcome: lack of standardized components, reliability, deploying a larger number of vehicles, and securing a reliable hydrogen fuel supply. The reviewer suggests that the principal investigator do a better job of documenting the causes for the excessive downtime in the fuel cell vehicles by itemizing the frequency of each component failure or cause of failure.

Reviewer 3

The proposed future research is a direct end product of the information that the project has established to date and a logical continuation for this RD&D project.

Reviewer 4

The reviewer said the project highlighted the key remaining challenges: lack of standardization, reliability, hydrogen fuel supply. Because several OEMs provided fuel cell trucks for the project, it would be nice to compare the pros and cons of each. This could help provide some insights in terms of which fuel cell powertrain approach works best.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer remarked the project supports DOE's effort to develop a decarbonized transportation system. The project is an avenue to put new technology into the field to help validate its viability and gain market acceptance.

Reviewer 2

The reviewer said this project is highly relevant and critical. First of all, the Ports of Los Angeles and Long Beach are in environmental justice communities which have been experiencing the adverse health effects of diesel for decades. Thus, this is an excellent geographic justification for this project. Second, the State of California has a mandatory goal of zero-emissions for drayage trucks by 2035. This is another excellent driver for this project. Third, there is no conceivable way for private industry to make a high-risk, high-cost investment in fuel cell engines with any certainty of a guarantee of return. Thus, a project of this nature must be federally funded.

Reviewer 3

The reviewer remarked this project is highly relevant to VTO's mission to advance zero emission and electrified heavy-duty vehicles.

Reviewer 4

The reviewer said the testing of previous fuel cell trucks is relevant. Not so sure about the CNG hybrid.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer noted this project is 10 years long, which is quite long. It is not clear why it needs to be that long. Nonetheless, the technology demonstration is an important part of testing the technology and should be very helpful to OEMs and future customers.

Reviewer 2

The reviewer said resources seem to be shifting as the scope has shifted but seem to be sufficient.

Reviewer 3

The reviewer said considering the high cost of the fuel cell engine, components, integration, and testing and the number of different vehicles, the reviewer believes that the resources appear to be sufficient.

Reviewer 4

The reviewer said resources for the remaining work are sufficient because the presenter did not identify 'lack of resources' as an issue affecting project performance.

Presentation Number: elt179
Presentation Title: Low Cost, High-Performance, Heavy Rare-Earth-Free 3-In-1 Electric Drive Unit
Principal Investigator: David Crecelius, American Axle & Manufacturing

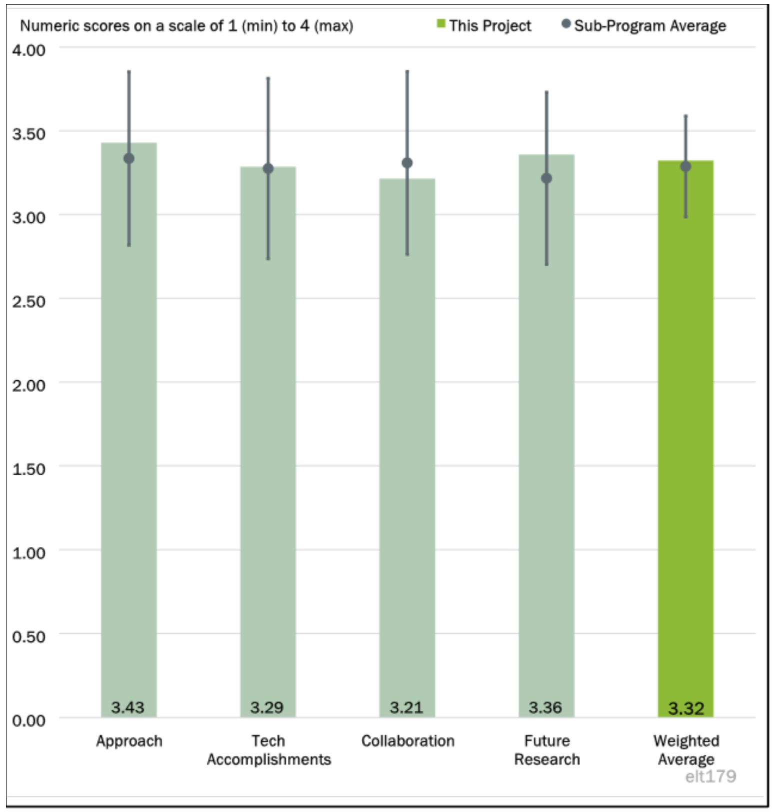

Figure 4-3 - Presentation Number: elt179 Presentation Title: Low Cost, High-Performance, Heavy Rare-Earth-Free 3-In-1 Electric Drive Unit Principal Investigator: David Crecelius, American Axle & Manufacturing

Presenter

David Crecelius, American Axle & Manufacturing

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said the project is well planned and progressing well to meet the objectives.

Reviewer 2

The reviewer noted that AAM's baseline technology, which is a Gen 5.0 3-In-1 electric drive unit (EDU), is illustrated in the project report along with key specifics. Budget period 1, Design Development and Technology Research, is completed and an optimized configuration of EDU is selected for fabrication in budget period 2. The reviewer noted that design (budget period 1) followed by fabrication (budget period 2) that leads to prototype for technology commercialization (budget period 3) is a logical and systematic approach for execution of this project. Also, the project's approach addresses VTO barriers, which is like effectively tying approach with relevance.

Reviewer 3

The reviewer commented the project is well-designed and planned. More discussion on the VTO barriers to be addressed (Slides 2, 7) would be helpful. Some specific information/data for how your project meets (or does not meet) performance, weight, and high-temperature limitations. During the Q &A, was it stated that the inverter design does not meet the 650V criteria?

Reviewer 4

The reviewer said this is an excellent project in which the technical barriers are addressed, and the project is well designed and planned. This reviewer is a bit confused by the presentation and description of the targets. It is not clear what exactly is included in the power density target for the electric traction drive system listed as greater than or equal to 12 kW/liter (e.g., motor + inverter, or motor+ inverter + transmission). The reviewer said some of the cooling configurations could be described more clearly in the slides.

Reviewer 5

The reviewer commented this project addresses various VTO technical barriers such as inverter barrier (high temperature and isolation materials for wide bandgap (WBG) switching devices), motor barrier (magnet cost and volatility), and performance barrier (performance of non-rare earth motors, and materials optimization). The project is well-defined and the timeline is reasonably planned.

Reviewer 6

The reviewer said the project aims to eliminate the use of heavy rare-earth (HRE) materials, increase power density and efficiency, and reduce cost. The project uses an induction motor, and the speed is 30,000, which is higher than other applications with similar power ratings.

Reviewer 7

The reviewer remarked well thought out plan. The plan encompasses all the appropriate evaluation criteria necessary for the technology to be commercialized.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer said excellent progress is being made on every element of the project.

Reviewer 2

The reviewer remarked well planned approach.

Reviewer 3

The reviewer said very good progress is being made on this innovative project, and the oil cooling pathway is intriguing.

Reviewer 4

The reviewer said technical accomplishments are good. These include the following: Stator design completed with improved slot liners and injection over molding of laminations and windings; high speed induction machine design analysis with the potential of efficiency close to permanent magnet (PM) motor; silver sintering process development for the SiC MOSFETs attachment; and optimal configuration selection for motor and drive-unit builds.

Reviewer 5

The reviewer remarked the project aims to trade off PM and induction motors. Induction motor speed is increased to 30,000 rpm using insulated induction motor rotor bars and optimized steel. Over-molded stator windings are used for thermal performance. Silver sintering is used for SiC devices for 650 Vdc buses. All of these aspects of the project support the project goals. The reviewer posed the following questions: What kind of rotor bar strategy is used, i.e., semi-open or closed slot, and what is the margin on mechanical design? It would be nice to show some analysis of mechanical design. The other question is, what would be the thermal cycling impact on the induction machine's rotor and any extended-term reliability issues? How is the rotor cooled?

Reviewer 6

The reviewer said the PI did a very good job summarizing and discussing project accomplishments, but the progress might additionally be understood if the PI had a waterfall chart tied to Slide 7,, which showed the improvement contribution amount of each solution. The reviewer liked the collection of baseline motor data and especially the PI's discussion of the performance of the chart on Slide 20.

Reviewer 7

The reviewer said the stator design of the completed EDU has improved slot liners and injection over molding of laminations and windings. Over molded stator design is illustrated in the project report with designed-in features that may allow high volume manufacturing. High speed induction motor design analysis shows high power density and drive cycle efficiency found close to permanent magnet motor. Initial silver sintering process for MOSFET is developed and bond line interface found acceptable and developed IP captured.

This reviewer raised a concern: Why do the silver sintered MOSFETs have high junction temperature. This may become worse over the ambient conditions (temperature sweep -40°C to 105°C) around silver sintered MOSFETs.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer remarked the project team has demonstrated sound collaboration with Electricore (project management), Encap Technologies (stator), MacDermid Alpha (sintering), and Breuckmann eMobility (rotor).

Reviewer 2

The reviewer said project progress is demonstrating that each of the partners are actively participating. Given the amount of work that has been completed, it is clear that each of these activities are being well coordinated.

Reviewer 3

The reviewer commented good collaboration among project partners has been outlined in the project report.

Reviewer 4

The reviewer said continue with the collaboration with the testing and evaluation.

Reviewer 5

The reviewer remarked all partners were documented. It might be interesting to understand who are the customers of this motor. For example, for the PI's baseline data, where are these motors used? Would it be worthwhile to understand potential customer comments once the bench test data and costs are complete?

Reviewer 6

The reviewer remarked overall, there is good collaboration and engagement with suppliers. It does not appear as though Electricore is performing any technical tasks.

Reviewer 7

The project works with industrial supplier partners, and Electricore is the sub-recipient.

The reviewer noted working with national labs and using their expertise in specific areas can strengthen a project. Is it possible in this project?

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer is highly interested in seeing actual results for performance improvements.

Reviewer 2

The reviewer remarked the future research outlined in the project report is supportive of tasks and milestones of budget period 2 and budget period 3.

Reviewer 3

The reviewer noted the presented listed barriers and challenges. Of course, it will be most interesting to understand the manufacturing/assembly/supply chain challenges during the assembly phase in stage 2. And of course if the testing shows limitations, will be good to understand the challenges of updating any needed design fixes.

Reviewer 4

The reviewer remarked the future research is good and well-defined.

Reviewer 5

The reviewer said the budget period 2 future research is well defined where a prototype will be fabricated and tested.

Reviewer 6

The reviewer said proposed future work involving prototype component fabrication, EDU cost estimation, build and test of the motor and EDU are all very well-motivated and the results should be interesting.

Reviewer 7

The reviewer noted that clear and logical next steps have been presented.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer remarked this is an important project to help determine the improvements in future cost and performance.

Reviewer 2

The reviewer said the project is completely relevant.

Reviewer 3

The reviewer commented the project is very relevant and supports VTO subprogram objectives of integrated EDUs with lower cost, higher power density, and good reliability.

Reviewer 4

The reviewer remarked the project supports VTO subprogram objectives of reducing dependency on heavy rare earths, while maintaining electrified drive unit performance, and reducing cost. The project team has shown a 10% cost reduction potential while maintaining PM-like efficiency.

Reviewer 5

The reviewer said this work is a great example of a well-defined project that focusses on risk reduction based on a complete understanding of the technology.

Reviewer 6

The reviewer noted that an induction motor that has performance and power density similar to a PM motor could be quite relevant to DOE objectives for electric machine technology needed for vehicle traction applications.

Reviewer 7

The reviewer said the project supports the overall VTO program objectives by eliminating the use of HRE materials, increasing power density and efficiency, and reducing cost. The project uses an induction motor with no permanent magnet motor. Speed is 30,000, which is higher than other applications with similar power ratings.

Question 6: ***Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?***

Reviewer 1

The reviewer said yes—resources appear to be sufficient.

Reviewer 2

The reviewer said resources seem to be sufficient.

Reviewer 3

The reviewer remarked it is difficult to judge how the assembly/build phase will proceed because there was no discussion on this point.

Reviewer 4

The reviewer said prototyping and testing are planned. It appears that resources are sufficient in this project.

Reviewer 5

The reviewer said project funding of $6.25 million over 3+ years is about right based on reviewer’s prior experience with such activities.

Reviewer 6

The reviewer said the project has all necessary resources, technical expertise, and know-how to successfully complete this project.

Reviewer 7

The reviewer remarked resources are appropriate.

Presentation Number: elt188
Presentation Title: Bi-Directional Wireless Power Flow for Medium-Duty, Vehicle-to-Grid Connectivity
Principal Investigator: Omer Onar, Oak Ridge National Laboratory

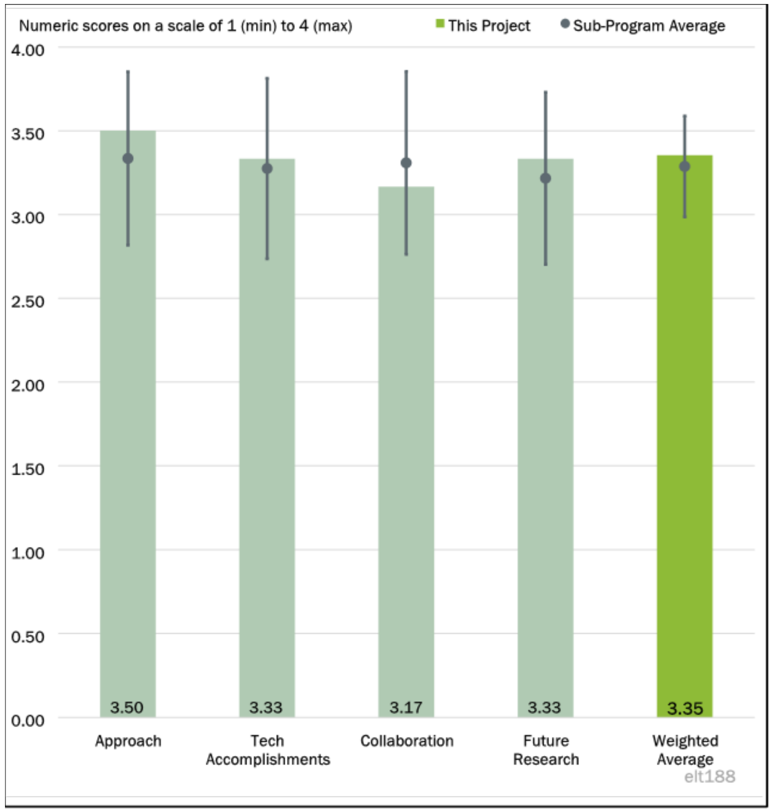

Figure 4-4 - Presentation Number: elt188 Presentation Title: Bi-Directional Wireless Power Flow for Medium-Duty, Vehicle-to-Grid Connectivity Principal Investigator: Omer Onar, Oak Ridge National Laboratory

Presenter

Omer Onar, ORNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of revi

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said good systematic approach.

Reviewer 2

The reviewer remarked the team is using a variety of approaches to minimize risk and enable iteration. For example, finite element analysis (FEA) allows for multiple iterations before committing to hardware and the use of battery and grid emulators enables testing of the hardware in a safe, laboratory environment. The team seems well-suited to the demonstration portion.

Reviewer 3

The reviewer commented the concept of the project is sound. It was a good change when 6.6 Kw to grid was abandoned in favor of 20kW. But... what is the demo duty cycle? Is it a daily bi-directional transfer? What data are you collecting regarding these transfers?

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer stated the presentation seems to focus on technical accomplishments in previous years. Fiscal year 2022 accomplishments seem to be fairly incremental.

Reviewer 2

The reviewer noted that system design, analysis, prototype, and lab testing were all successful. Except for the 1-year COVID-19 pause, this project has completed tasks within original allotted time frames. Nice job.

The reviewer said that if CALSTART is doing a business case, why is it not being reported.

Reviewer 3

The team has made excellent progress in all aspects of the project after recovering from COVID-19-related delays. The team has exceeded their targeted power handling in the vehicle-to-grid (V2G) application. The PIs have identified the challenges associated with light load and are working to improve efficiency, which is already very good for this stage of the project.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer remarked there seems to be good level of collaboration among partners.

Reviewer 2

The reviewer said it is clear that ORNL and UPS are tightly coupled with great collaboration and coordination. The other team members are also clearly contributing and engaged.

Reviewer 3

The reviewer said the project lead entity did not participate in the presentation, and no explanation was given.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said as this project transitions to a full deployment, the team has made appropriate modifications to the equipment that will enable effective integration with the target facility's workflow and infrastructure. At the end of the project, the equipment will reach a higher technology readiness level than originally targeted.

Reviewer 2

The reviewer remarked the system design build and testing was very well presented. Until the question was asked, at no time was any information given as to what the future work, namely the demonstration phase, was intended to accomplish and why it was important. Bi-directional wireless power transfer is only a 'nice to have' unless it is understood how UPS will use this feature. It is not for emergencies as UPS facilities have back-up power systems. The reviewer asked how will the benefits of having it be measured in a demonstration. The speaker said this could be a separate project but because the project says it includes a 6-month demonstration, the reviewer respectfully disagrees with that statement. Again, the project lead should have provided a slide to describe what the future work was intended to accomplish.

Reviewer 3

The reviewer said that verification testing in the actual vehicle is needed.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said timely topic that can help meet the DOE objectives.

Reviewer 2

The reviewer said it is relevant to the VTO goals.

Reviewer 3

The reviewer commented this project provides bidirectional capability to wireless charging infrastructure to enable both smart charging and V2G applications. For large truck depots, even with relatively low-power operation, the aggregate impact can be substantial.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said resources are sufficient based on project scope.

Reviewer 2

The reviewer remarked timely completion of tasks indicates that resources are 'right sized.'

Reviewer 3

The reviewer said the team seems to be well-positioned to deploy the prototypes and gather appropriate field data.

Presentation Number: elt197
Presentation Title: High Power and Dynamic Wireless Charging of Electric Vehicles
Principal Investigator: Veda Galigekere, Oak Ridge National Laboratory

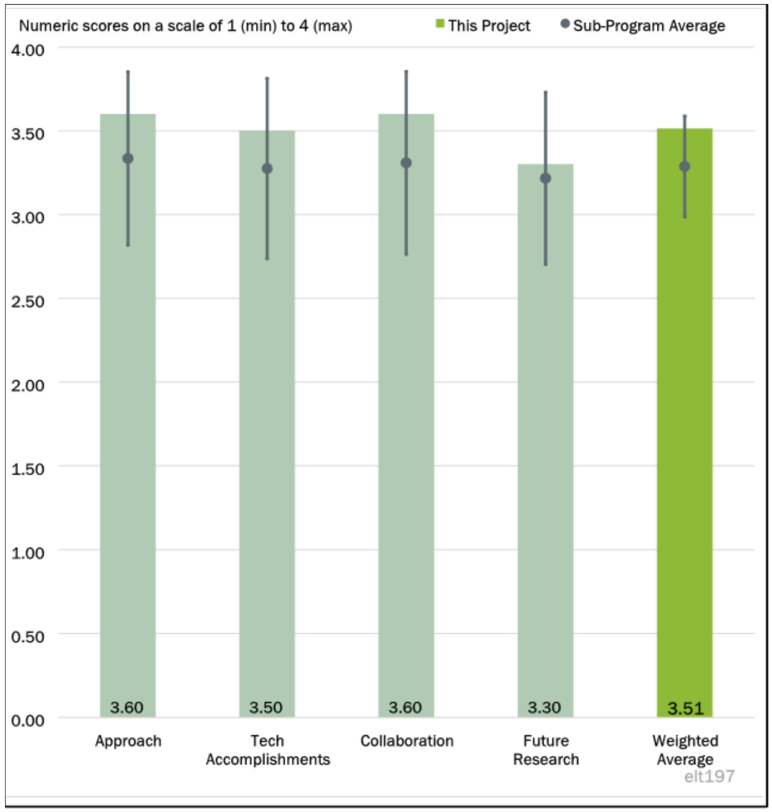

Figure 4-5 - Presentation Number: elt197 Presentation Title: High Power and Dynamic Wireless Charging of Electric Vehicles Principal Investigator: Veda Galigekere, Oak Ridge National Laboratory

Presenter

Veda Galigekere, ORNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said the project was extended due to COVID-19-related delays. It is on schedule to be completed 6 months later than planned. Lead times for parts are all longer so the project demonstration is taking longer. That seems reasonable. The studies and design work were followed by hardware development then lab validation ending project with real world demonstration. Great approach to the project and barriers that are being addressed. The real-world demonstration will take place at the American Center for Mobility (ACM), which is set up to take data in all seasons. The ACM should be able to test real world conditions such as rain and salt's impact on the charging equipment and processes.

Reviewer 2

The reviewer said very good systematic approach.

Reviewer 3

The reviewer remarked this work is well planned. Technical milestones are properly defined and are measurable. However, the project is delayed from original schedule.

Reviewer 4

The reviewer said the work done so far has been great—especially with reference to light-duty (LD) vehicles. The main concern is that with LD vehicles, range anxiety is less problematic especially when compared to medium-duty (MD) and heavy-duty (HD) vehicles (Class 3, 4, 5, and above), because the range takes a huge hit when towing a trailer. For LD vehicles in most cases, there could possibly be sufficient battery capacity to alleviate range anxiety, but it is quite otherwise with MD and HD vehicles with high gross combined weight rating. It would help if there is a stronger focus on these scenarios, and what requirements they may bring to the design of the dynamic wireless power transfer (DWPT) system.

Another concern is the damage that the system can sustain during winter, when the repeated freeze-thaw cycles cause huge potholes to show up. How would maintenance of these be managed? And if vehicles are designed with the assumption that DWPT would always be available, what happens when the system is down due to potholes or any other reason. Most OEMs may have to design their vehicles to handle the situation where DWPT may be temporarily unavailable, which may negate the benefit by resulting in large batteries being required.

Reviewer 5

The reviewer remarked the technical barriers with electronics (power and efficiency), shielding, and data acquisition have been clearly defined and addressed. There is little doubt that the team will have a system meeting the technical goals established at project inception.

The reviewer said discussion of electromagnetic (EM) shielding and effects on humans as well as cost should receive much greater attention. The team did not identify standards for acceptable electromagnetic (EM) exposure. Additionally, the cost/benefit was optimized for a DWPT enabled infrastructure, but not compared with alternative technical solutions. The cost of electrifying up to 16% of long-distance highway routes must be addressed to undergird the credibility of the project.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer said the team has achieved significant technical milestones and made excellent progress.

Reviewer 2

The reviewer commented the PI described lots of accomplishments. The team worked their way up from smaller to larger more complicated aspects of the project. The team was able to look at the vehicle and confirm there were no hot spots. Additionally, the team address potential hot spots with aluminum as a means of risk mitigation. The laboratory demonstration should be conducted at 20 mph. Thus far the team has demonstration charging in the lab at up to 10 mph. There are no standards for dynamic charging so the PI and his team have targeted emissions compliance at the edge of the driving lane and in the vehicle. It is appreciated that the team created the boundaries needed to move forward in the analysis and project in the absence of data.

Reviewer 3

The reviewer stated very good progress and risk mitigation

Reviewer 4

The reviewer said this is a little behind schedule due to COVID-19, but excellent progress overall. The results of the testing at ACM should be interesting.

Reviewer 5

The reviewer remarked the project has fallen somewhat behind a rather aggressive schedule. Dynamic validations and the data acquisition challenges associated with them remain to be accomplished. It is not clear where the project is with respect to budget. It is showing 100% complete on the Overview slide, inferring that the budget has been exhausted, with some significant work remaining.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said very good collaboration effort between a national lab, OEMs, and universities.

Reviewer 2

The reviewer commented excellent collaboration and well-defined roles among partners.

Reviewer 3

The reviewer remarked the project team has a good group of lab staff, OEMs, and academia. While no transportation agencies or utilities are part of the team, the team is in communication with Florida's and Georgia's Department of Transportation as well as TVA and other utilities. The PI acknowledged that they have not started discussions with Federal Highways and should be in communication with them. While the PI explained that an electric vehicle supply equipment (EVSE) member of the team had pulled out of the project. These things happen. It would have been nice to see them engaging with some sort of manufacturing or installation perspective to understand what it would take to create and install this solution in the real world. Perhaps that is a follow-on project.

Reviewer 4

The reviewer said the team has correctly identified areas for technical and non-technical collaboration. Next stage will require close partnership to deliver field demonstrations.

Reviewer 5

The reviewer commented the team has joined the appropriate technical talent from multiple national laboratories. Excellent collaboration and coordination are evident in the hardware development and testing to date. The reviewer suggested that the team expand to include safety and cost analysis resources to examine non-technical barriers to project feasibility.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer pointed out that real life testing is critical for proving the concept.

Reviewer 2

The reviewer remarked the project team has describe the pending demonstration and the data planned for that demonstration. Deep dive discussions will take place under the Electric Vehicles at Scale (EVs@Scale) Consortium.

Reviewer 3

The reviewer referred to a prior question, and believes there are still many issues that need to be addressed. As previously mentioned, an OEM would design a vehicle that would not lose functionality based on availability or non-availability of the DWPT. Customers may not be accepting of a vehicle that provides severely reduced functionality when the DWPT charging network is down for whatever reason. This would require over-design of the energy storage system.

The reviewer noted that another scenario that should be investigated is the requirements and response of the system during extreme weather events, such as Hurricane Rita. The reviewer hadseveral friends who had to get out of Houston, and were stuck on roads with bumper to bumper traffic for hours. What requirements do such events impose on the design of the DWPT system?

Reviewer 4

The reviewer said the project is extremely focused on demonstrating technical feasibility. This appears to be without recognition of non-technical issues like safety and cost. Future work continues to be only technically focused. A more detailed look at EM exposure and system cost should be a part of future work.

Reviewer 5

The reviewer commented proposed future research should be made more comprehensive.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said the project is very much relevant to VTO's Electrification and Energy Efficient Mobility Systems programs.

Reviewer 2

The reviewer remarked timely topic that can help meet the DOE objectives.

Reviewer 3

The reviewer remarked dynamic wireless charging enables high power and interoperable charging. If the technology becomes widespread it could also bring down the size of the batteries in vehicles and the electric vehicle's (EV) cost. These are important factors in electrifying fleets. The reviewer recognizes that those costs would be distributed to the grid and road infrastructure, but believed that would be okay.

Reviewer 4

The reviewer said this is a very relevant project for achieving wide adoption of EVs and electrical infrastructure support.

Reviewer 5

Again, the project must address safety and cost if it is to have credible relevance. The reviewer specified the project should look at a broad range of applications to determine where the DWPT can be relevant from a cost perspective and can assure public safety in a litigious environment.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said at this point the resources appear to be sufficient.

Reviewer 2

The reviewer remarked resources are sufficient based on proposed scope

Reviewer 3

The reviewer said the resources for the project seemed sufficient.

Reviewer 4

The reviewer said the project required additional support to complete next steps in time.

Reviewer 5

The reviewer said technical resources across a broad spectrum of capabilities have been applied to the project. Non-technical aspects of the project (safety and cost) should receive the same level of resource commitment.

Presentation Number: elt208
Presentation Title: Highly Integrated Power Module
Principal Investigator: Lincoln Xue, Oak Ridge National Laboratory

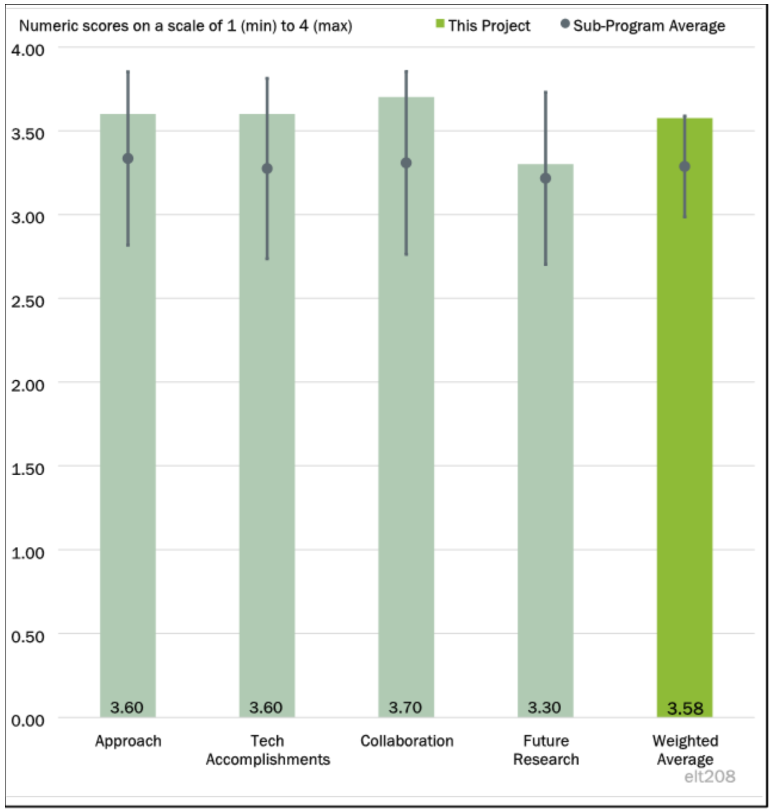

Figure 4-6 - Presentation Number: elt208 Presentation Title: Highly Integrated Power Module Principal Investigator: Lincoln Xue, Oak Ridge National Laboratory

Presenter

Lincoln Xue, ORNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said the project develops new cooling method for power semiconductor devices. Genetic algorithms are used to optimize the heat sink topology. Simulation and test results have demonstrated significant thermal performance improvement. The reviewer said the project is well designed and the timeline is reasonably planned.

Reviewer 2

The reviewer said the project aims (design and cooling improvements) are appropriate to the task of shrinking the power module to meet the overall 100kW/L inverter requirement.

Reviewer 3

The reviewer remarked this project is a comprehensive approach for addressing the technical barriers for high-density packaging of EV drives.

Reviewer 4

The reviewer commented the technical approach of the research is excellent; however, the reviewer wanted to see some identification of reliability and cost versus current industry standard. Perhaps a chart or table that summarizes and compares temperature/power density/cost to other approaches. The team states that reliability of current power modules is difficult to obtain, but perhaps you can assign this task to one of your partners, along with a cost identification procedure. The reviewer asked will the reliability target be a combination of thermal cycles and vibration loading? How will the final test be performed and/or simulated?

Reviewer 5

The reviewer remarked a low-cost and high-power density SiC inverter that has 15 years and 300,000 mile life-time is needed for wide adoption of WBG technology in vehicle traction applications. This project attempts to address DOE's Electrification program's (ELT) 2025 targets for cost, power-density, reliability, and efficiency.

This reviewer has huge concern with selection of 2 kV breakdown voltage between electrical live parts/sections and touch-safe portion (heat-sink) in the highly integrated power module. Performers must raise this breakdown voltage to 5 kV for 800V direct current (DC) bus inverter.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer remarked the team has completed the quarter 1 and quarter 2 milestones for fiscal year (FY) 2022. Results have shown significant thermal performance improvement. Other milestones are on track. Overall, the team is making outstanding progress.

Reviewer 2

The reviewer remarked electrical (gate driver and power circuit) and thermal (heat sink, heat sink, and thermal interfaces) designs and performances (SiC die temperature rise for jet impingement method) thereof for a highly integrated SiC power module are completed and the rest of technical progress is on track.

Reviewer 3

The reviewer said the team has shown excellent results so far. The cooling performance achieved is encouraging but raised a few questions: Why was 1.6 lpm flow rate a constraint for the indirect-cooling system when the jet-impingement system was evaluated at rates up to 3.2lpm? Have you considered the manufacturability of the optimized heat sink? It looks non-uniform in shape

Reviewer 4

The reviewer said very good explanation of accomplishments. The reviewer wished that the team would have had one final slide that tabulated the results.

Reviewer 5

The reviewer said the team has made significant technical progress on all parts of the technical approach: gate-driver integration, substrate materials, cooling designs, and experimental validations. This reviewer urges the team to construct prototypes of the integrated power module and demonstrate them in a 100 kW/L power density inverter.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said great collaboration between university, government lab, and industry to achieve the project result. Each sector has made a key contribution and lent specific expertise to the project. The involvement of DuPont for their direct bonded copper material is notable.

Reviewer 2

The reviewer remarked the team's collaboration partners have extensive R&D expertise covering all parts of the proposed work.

Reviewer 3

The reviewer said all project partners are working to successfully complete project tasks and have timely delivery of milestones

Reviewer 4

The reviewer commented collaboration between team members is well coordinated.

Reviewer 5

The reviewer was unclear how important each of the partner deliveries are to the project outcome.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer remarked the proposed future research is clear and appropriate. The likelihood for the team to achieve its target is high based on the results presented for the new cooling design.

Reviewer 2

The reviewer remarked next steps are clearly outlined and seem to be manageable given the progress to date.

Reviewer 3

The reviewer said proposed future work is well planned, but challenging. A key challenge will be from ensuring a high enough yield in module packaging and assembly.

Reviewer 4

The reviewer said necessary tasks and plans are described in project presentation document.

Reviewer 5

The reviewer said the discussion of remaining barriers to be addressed was limited. The reviewer thought this slide should have more content/discussion, especially around potential problems that might arise in prototyping, costing, or testing.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer commented improving power electronics capability and performance is key to enabling electrification. The research may lead to higher performance, lower cost, more compact systems that can be used in EVs.

Reviewer 2

The reviewer noted that successes of this project are necessary for DOE VTO to meet its 2025 EV drive targets.

Reviewer 3

The reviewer said completely relevant.

Reviewer 4

The reviewer remarked yes, a high power density SiC inverter supports VTO's 2025 targets

Reviewer 5

The reviewer remarked the project supports VTO subprogram objectives by developing new cooling methods for power semiconductors to achieve higher power density for power converters of vehicles.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer noted that researchers did not indicate any areas where they are in need of additional resources to meet the project requirements.

Reviewer 2

The reviewer said resources are sufficient.

Reviewer 3

The reviewer said the project has the necessary resources and plan to execute project tasks and meet milestones.

Reviewer 4

The reviewer remarked the team has excellent resources to achieve the stated milestones.

Reviewer 5

The reviewer commented it was somewhat difficult to judge this without more information about the budget breakdown and work of the partners.

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

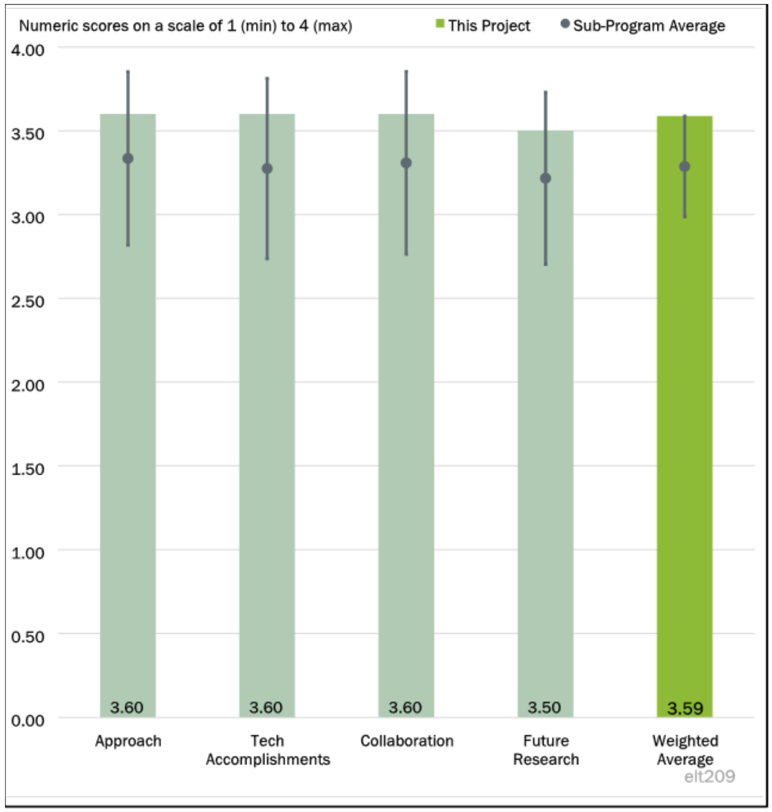

Figure 4-7 - Presentation Number: elt209 Presentation Title: High-Voltage, High-Power Density Traction-Drive Inverter Principal Investigator: Gui-Jia Su, Oak Ridge National Laboratory

Presenter

Gui-Jia Su, ORNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said the project approach tackles a number of issues that would enable the project goal: Interesting inverter topology and control applied to reduce capacitor size for smaller package; use of SiC devices for higher efficiency (lower heat generation) and system cooling. The results look promising.

Reviewer 2

The reviewer said the team has a clear, well-thought approach for the project.

Reviewer 3

The reviewer said the team uses the interleaved switches, optimized bus bar, and capacitor design to increase the power density of a vehicle power converter. The team demonstrated a 100-kW prototype. The results show the design meets the power density target 100 kW/L. The reviewer suggested the team show the cost analysis next year.

Reviewer 4

The reviewer remarked a very good overall approach of the various activities needed to deliver the overall power system density goal. However, there was too little discussion supporting the reliability and cost goals for a typical application. Also, a discussion on how the overall system performs was lacking. The approach of each activity was well defined and discussed, but how the solutions work and deliver the overall system performance needs further documentation.

Reviewer 5

The reviewer commented the team has used a systematic and step by step approach to resolve technical barriers to achieve power-dense (100 kW/L) low cost ($2.7/kW) high efficiency (greater than 97%) reliable (300,000 miles endurance or 15 years life). However, this reviewer has severe doubt that project team will ever meet cost target of $2.7/kW.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer said outstanding progress. Keep up the great work.

Reviewer 2

The reviewer said the team has built a 100-kW inverter prototype and got preliminary test results to meet the power density target. The team plans to fully characterize the 100-kW prototype by the end of quarter 3 of FY 2022. The reviewer considers this outstanding progress and suggests the team show comprehensive test results of this 100-kW prototype in next year's review.

Reviewer 3

The reviewer noted the team has developed and tested a 100kW inverter. The 200kW unit design is a little short of the 100kW/L target but impressive nevertheless. We look forward to seeing how it performs. It would be useful for the reviewers to compare the design to an industry benchmark design.

Reviewer 4

The reviewer remarked good supporting data, charts, and pictures to support the accomplishment discussion. It would be helpful at the end of the accomplishment discussion to show a waterfall chart that summarizes the performance contribution of each component and sums up the performance improvement expected with the inverter system.

Reviewer 5

The reviewer said progress is quite good. In Slide 14 of the project report, data shown on left side of slide including junction temperature rise do not match with data shown in Table on right side of this slide. Symmetrical space vector pulse width modulation (SVPWM) technique is indicating lower junction temperature in the far left-side illustration while table on the far right shows that bus-clamp SVPWM renders lower junction temperature. The reviewer requested the project team to clarify this discrepancy.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer remarked collaboration between team members is well coordinated.

Reviewer 2

The reviewer said all entities/partners in the project team are collaborating as expected of them.

Reviewer 3

The reviewer noted excellent collaboration on key tasks across a number of organizations. The accomplishments to date would be difficult without close communication and collaboration.

Reviewer 4

The reviewer said a great group of collaborators.

Reviewer 5

The reviewer was not entirely clear how the university input is being used. Is Virginia Tech only responsible for 100kW modules and the University of Arkansas only responsible for 200KW modules?

Question 4: Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1

The reviewer said next steps are important follow-ons to the work completed. The 200kW inverter in hardware should be very interesting and challenging (to reduce the volume by 0.6L!).

Reviewer 2

The reviewer said excellent plan, but the future work is challenging.

Reviewer 3

The reviewer said well done listing challenges that have been uncovered and being open to tackle new ones. However, the reviewer would have appreciated seeing more documentation on this slide.

Reviewer 4

The reviewer remarked the plan is described and will lead to a successful project outcome. Technology commercialization is not clear and probably there is no possibility to commercialize the technology that is under development.

Reviewer 5

The proposed future research is clear and timeline is reasonable. The likelihood of achieving the targets is high.

The reviewer suggests the team show comprehensive test results of 100-kW and 200-kW prototype in next year's review and add cost analysis.

Question 5: Relevance: Does the project support the overall VTO subprogram objectives?

Reviewer 1

The reviewer said the project supports the VTO subprogram objectives by using interleaved switches, optimizing bus-bus design, and reducing the size of passive components to increase the power density of vehicle power converters.

Reviewer 2

The reviewer said the work supports advancement in component design for electrification. More compact, efficient power electronics enables better EV vehicle design for usable driving range.

Reviewer 3

The reviewer said yes.

Reviewer 4

The reviewer said highly relevant.

Reviewer 5

The reviewer noted the project attempts to meet DOE's ELT 2025 target except the cost target of $2.7/kW, which seems not possible to achieve.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said resources appear sufficient. One supposes more resources would get the job done faster but progress is excellent with the current funding.

Reviewer 2

The reviewer remarked resources are sufficient.

Reviewer 3

The reviewer said the team has excellent resources to achieve the stated milestones in time.

Reviewer 4

The reviewer commented the project team has all necessary resources, except supply chain issues may be not be adequately addressed by project team, which may cause unnecessary delay in completion of project tasks and delivery of milestones.

Reviewer 5

The reviewer remarked difficult to judge this because the total project budget was not shared. However, no issues were highlighted by the speaker.

Presentation Number: elt210
Presentation Title: Development of Next-Generation Vertical Gallium-Nitride Devices for High-Power Density Electric Drivetrain
Principal Investigator: Andrew Binder, Sandia National Laboratories

Presenter

Andrew Binder, SNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of revi

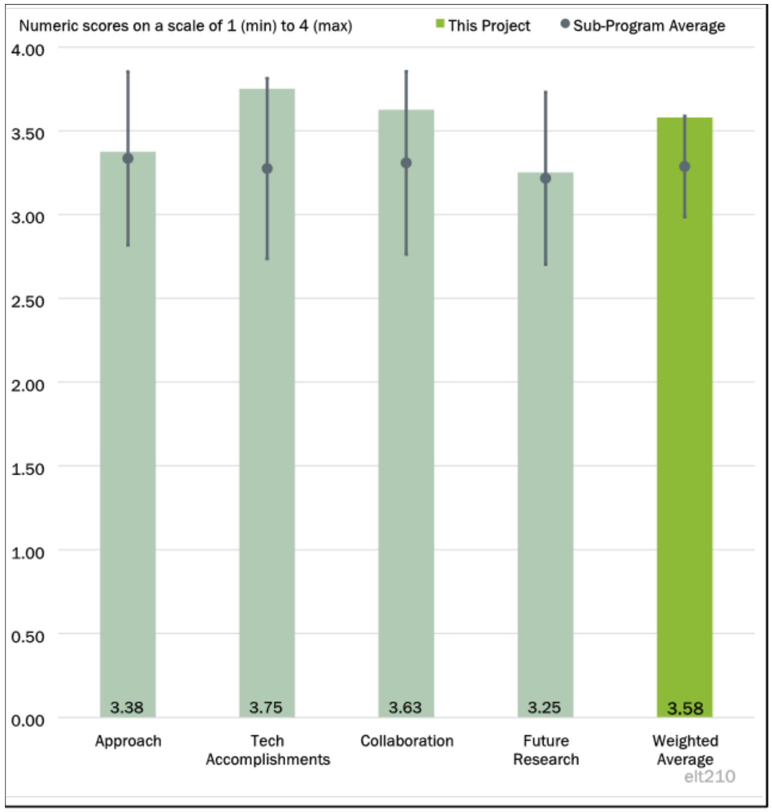

Figure 4-8 - Presentation Number: elt210 Presentation Title: Development of Next-Generation Vertical Gallium-Nitride Devices for High-Power Density Electric Drivetrain Principal Investigator: Andrew Binder, Sandia National Laboratories

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said the project has made outstanding progress.

Reviewer 2

The reviewer noted this was descried in the Slide 6 of project report. The project team is taking a three-steps approach, which is step-by-step problem solving to start with the easier one first to be solved.

Reviewer 3

The reviewer said the project is tightly focused on the basic mechanical challenges of building gallium nitride (GaN) devices. The project provides fundamental techniques that can be used to make GaN a reality for industry use. A weakness is lack of an industry partner that would build such devices. I think that would really unlock the power of this research.

Reviewer 4

The reviewer was not entirely clear how the GaN development is tested to prove it is a viable solution for an inverter design. The actual work plan for the coming year and to project completion was not discussed enough. This topic needs more discussion but most of the time was taken by discussion of accomplishments.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer noted that surface induced leakage current from passivation is a difficult problem for GaN-based power devices and it seems like the project has solved this issue along with tracking on many challenging issues related to the development of vertical GaN devices (MOSFET and junction barrier Schottky [JBS] diode).

Reviewer 2

The reviewer said the team has achieved all milestones.

Reviewer 3

The reviewer remarked technical progress in demonstrating fundamental performance capability with the techniques developed in the project is impressive.

Reviewer 4

The reviewer appreciates the many boxed notes on each accomplishment slide.

As expected, there are many accomplishment slides highlighting a variety of the design aspects. The reviewer said the team needs an accomplishment summary slide at the end of the discussion.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1F

The reviewer remarked the team has correctly identified all relevant parties.

Reviewer 2

The reviewer appreciated the description of each partner's work on the collaboration slide.

Reviewer 3

The reviewer said collaboration is excellent but as mentioned in a prior question, it seems the team needs a device maker that is working on GaN to really be able to exploit your techniques and indicate where improvements can be made.

Reviewer 4

The reviewer said that the project team led by Sandia National Laboratories (SNL) has many entities in this collaborative project and collaborative activities as per expectation in finding technical solution for the 1200 V GaN devices (MOSFET and JBS diode).

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said future work described is appropriate follow-up to the progress made so far.

Reviewer 2

The reviewer remarked well done.

Reviewer 3

The reviewer remarked as expected, GaN-based JBS, MOSFET, and circuit system level research is outlined in the project report and orally described during the presentation in AMR.

Reviewer 4

The reviewer said proposed future research is logical and aligned with project objectives.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer commented the project is highly relevant to making GaN an everyday option for electrification. GaN will allow more robust EV performance and increase efficiency by reducing cooling requirements.

Reviewer 2

The reviewer remarked a vertical GaN MOSFET is needed, as for an 800V DC bus GaN inverter, there exists no WBG device. Therefore, power conversion systems' integrators are left with the option of using either a SiC 2-level inverter or a 3-level GaN inverter. A 2-level inverter is quite simplified and reliable too compared to the 3-level GaN inverter. Therefore, a vertical GaN MOSFET with 1200V blocking is needed. Also, per the reviewer, a GaN MOSFET will fulfill DOE ELT 2025's targets of the power-density (100 kW/L) and probably cost ($2.7/kW) too.

Reviewer 3

The reviewer said the project is aligned with VTO objectives on electrification.

Reviewer 4

The reviewer would like to see a summary of the breakdown of requirements for each solution topic and the status to goal.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said progress is good. Resources appear adequate.

Reviewer 2

The reviewer said the project has sufficient resources.

Reviewer 3

The reviewer said although the project team has necessary resources, the team must have its eye on any supply chain related issue, particularly system level (power conversion circuit) insertion of the 1200V rated GaN MOSFET.

Reviewer 4

The reviewer remarked difficult to judge because the total project cost is not listed. Also, is the project operating with a no cost extension? In that case, are the partners on-board for delivering the work? Will the team be able to finish the project?

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

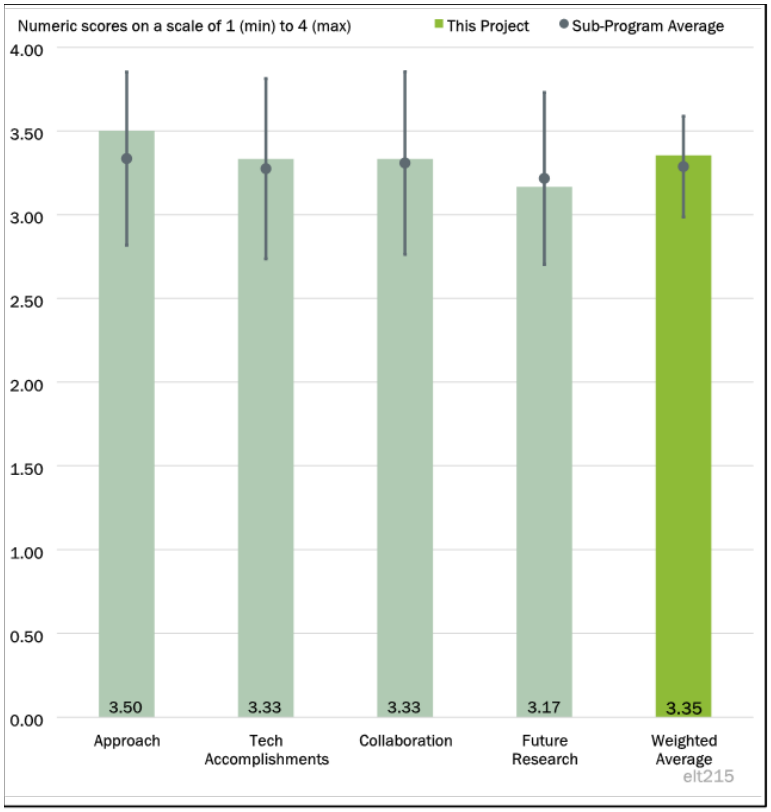

Figure 4-9 - Presentation Number: elt215 Presentation Title: Permanent Magnets Without Critical Rare Earths to Enable Electric Drive Motors with Exceptional Power Density Principal Investigator: Iver Anderson, Ames Laboratory

Presenter

Iver Anderson, Ames Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of revi

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer remarked the project addresses a critical technology gap in the supply chain for electric vehicles. Future increases in domestic EV manufacturing require higher performance magnetic materials with a resilient supply chain. The approach to solving the technical barriers is rigorous and well planned. Deviations from the original plan to use a jet mill at a corporate partner was not possible due to pandemic related delays, but the team has effectively pivoted to other approaches.

Reviewer 2

The reviewer noted the project aims to reduce PM costs and eliminate use of HREs, which are scarce and costly. The project aims to create a better magnet using ultrafine grain technology to improve the motor design. The goal is to achieve cost-effectiveness and high efficiency. The project has a step-by-step process to create this new magnet using material science technology. The timeline is well planned.

Reviewer 3

The reviewer said the projected improvement in coercivity compared to commercially available HRE-free magnets is encouraging. The reviewer was not clear if the work on soft magnetic materials is continuing or not.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer said the quantification of motor performance based on achieved/projected properties should be included.

Reviewer 2

The reviewer remarked the approach to achieving improved magnetic properties has achieved good progress at the lab scale, and further progress depends on demonstration with production scale equipment.

Reviewer 3

The reviewer noted the projects aims to create impact using ultrafine grain magnets to reduce PM motor eddy current losses and improve PM motor power density. Reducing cost and increasing efficiency at elevated temperatures are targeted. If successful, this project enables designs with less PM cooling. The reviewer said the team developed an NFR passivation apparatus and carried out a trial run. The project established a relationship among passivation parameters, power oxidations, etc.

The reviewer said it has been shown that an ultrafine-grain HRE-free rare Earth (RE)-PM can raise coercivity and stabilize high-temperature properties. Feedstock and commercial strip cast HD are successfully used. The research concluded that 5% Pr-Cu is a good choice.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer noted this project collaborates well with ORNL for motor design advances, NREL mechanical and thermal aspects, and SNL for coordination with universities.

Reviewer 2

The reviewer remarked the level and details of collaboration are not very clear.

Reviewer 3

The reviewer said collaboration between Ames National Laboratory, ORNL, NREL and SNL was mentioned but little data was presented.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer commented the plan includes access to a multi-jet milling process for alternative passivation of ultrafine grains. Plans also include optimizing the chemistry of the magnet and better understanding mechanical properties for motor use.

Reviewer 2

The reviewer said the plan seems satisfactory.

Reviewer 3

The reviewer remarked proposed future research to use multi-jet milling will be very important and critical to the success of the project.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said reduction and/or elimination of RE material is a strategic goal that is consistent with DOE targets.

Reviewer 2

The reviewer said yes, the program is relevant to the DOE Electrification subprogram. Meeting the goals on the EV roadmap will require improvements to magnetic material performance and a resilient supply chain.

Reviewer 3

The reviewer remarked yes, the electrification of vehicles requires traction motors that are low-cost and efficient. This project is relevant to getting rid of HRE and developing alternative technology for traction motors of all kinds of electric vehicles.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said resources are sufficient based on the proposed scope.

Reviewer 2

The reviewer said it seems like the only issue is the multi-jet milling capability. Pandemic and other supply chain issues appear to limit the access to multi-jet technology. Other than that, it seems like progress is happening as planned.

Reviewer 3

The reviewer remarked the team has sufficient resources to carry out the program objectives. However, completing the program will require access to a multi-jet mill that is not available within Ames National Laboratory.

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

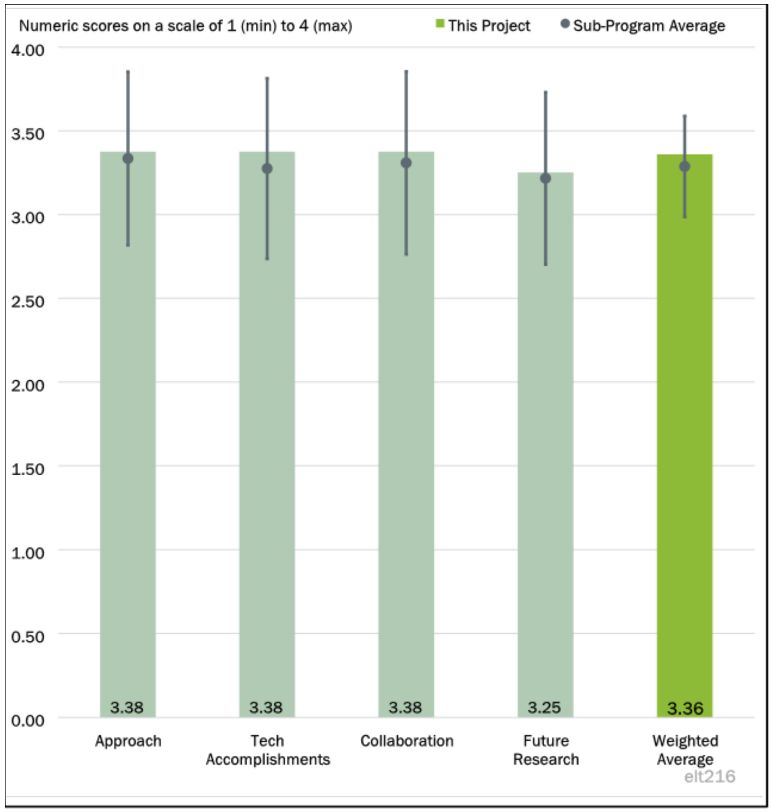

Figure 4-10 - Presentation Number: elt216 Presentation Title: Isotropic, Bottom-Up Soft Magnetic Composites for Rotating Machines Principal Investigator: Todd Monson, Sandia National Laboratories

Presenter

Todd Monson, SNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer detailed this project aims to develop soft magnetic materials for electric motors. This material can be significant for homopolar and axial machine designs where PMs are not used. Hence, this project is timely to eliminate RE elements that are used in PMs.

The proposal mainly focuses on iron nitride/epoxy composites to create soft magnetic material. The project focuses on fabricating, curing, and polishing these soft magnetic materials using iron nitride with different percentages for volume.

Reviewer 2

The reviewer remarked the project is well planned and is methodically addressing the technical barriers needed to demonstrate the ability of iron-nitride powder filled epoxy composites to perform as soft magnetic motor components.

Reviewer 3

The reviewer said the team developed a new soft magnetic composite material that uses cheap and abundant elements. The team targets to achieve 1.89 T saturation polarization. The most updated work has achieved 1.19 T and the team plans to further improve the saturation level. The mechanical strengths of the magnetic composite material are significantly lower compared to those of silicon steel. The reviewer's suggestion is not to use the magnetic composite material to build the machine rotor. If the team can achieve 1.89 T saturation polarization in the coming years, using this material to build machine stators to improve performance is still a success.

Reviewer 4

The reviewer said the project should provide a comparison of the projected properties to other lamination materials.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer said the team has made excellent progress towards reaching the goals of the project. The technology tasks are appropriate and the rate of progress has been to plan.

Reviewer 2

The reviewer commented the project analyzed and tested the mechanical strength of iron nitride and epoxy. It has been found that the volume % loading of iron nitride can be more than 75%. This technology can also be used for inductors and achieve low loss soft magnetic material alternative instead of laminated steels and ferrites. The goal of the project is to achieve high magnetization levels to be applicable for both motor and inductor designs.

Reviewer 3

The reviewer noted the team plans to finish evaluating the mechanical properties of components made by the new magnetic composite material by 6/30/2022. Dog bone samples have been made and testing is in progress. Overall, the project is on track.

Reviewer 4

The reviewer said it is hard to quantify based on the provided information and the expected benefits of the proposed material. At least motor simulation results should be provided.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer thinks the project collaborates well with other national labs and universities, i.e., Purdue and Illinois Institute of Technology-Chicago.

Reviewer 2

The reviewer said collaboration between team members is well coordinated.

Reviewer 3

The reviewer remarked the team has made excellent use of the facilities at NREL and Ames National Laboratory for physical property measurements unable to be performed at SNL. Other than the homopolar motor concept from Purdue University, the contributions from the other partners was not presented.

Reviewer 4

The reviewer commented the roles of all the partners are not very clear; for example, there seems to be an overlap between Purdue, Illinois Institute of Technology, and ORNL.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said the team has a clear goal to improve the saturation polarization from 1.19 T to 1.89 T as the volume loading increases.

Reviewer 2

The reviewer said the project needs more quantification of material properties and motor performance.

Reviewer 3

The reviewer remarked measurement of the mechanical properties will be critical towards understanding the ability of this material to perform in an electric machine. More detail on the prototype motor designs under consideration should be presented in future reviews.

Reviewer 4

The reviewer said future work includes mechanical testing and improving the soft composite material performance. The reviewer asked is it possible to show an example motor design using the properties of the soft magnetic material that would be useful to show next year.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said an improved soft magnetic material with lower losses can help meet the DOE targets.

Reviewer 2

The reviewer remarked yes, the project is relevant to the Electrification subprogram. Meeting the performance goals on the DOE roadmap will require advances in magnetic material performance.

Reviewer 3

The reviewer remarked the project explores new magnetic material to improve the power density for traction machines for electrified vehicles.

Reviewer 4

The reviewer said the project supports the VTO subprogram objectives related to motor design using on-HRE materials. The reviewer asked is it possible to design a motor and inductor using this material in the future? What would it take to create a sample rotor and stator?

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said resources are sufficient based on the proposed scope.

Reviewer 2

The reviewer remarked resources are sufficient to meet the goals of the project.

Reviewer 3

The reviewer said it appears that resources are sufficient.

Reviewer 4

The reviewer commented the team has excellent resources to perform the planned research.

Presentation Number: elt217
Presentation Title: Integrated/Traction Drive Thermal Management
Principal Investigator: Bidzina Kekelia, National Renewable Energy Laboratory

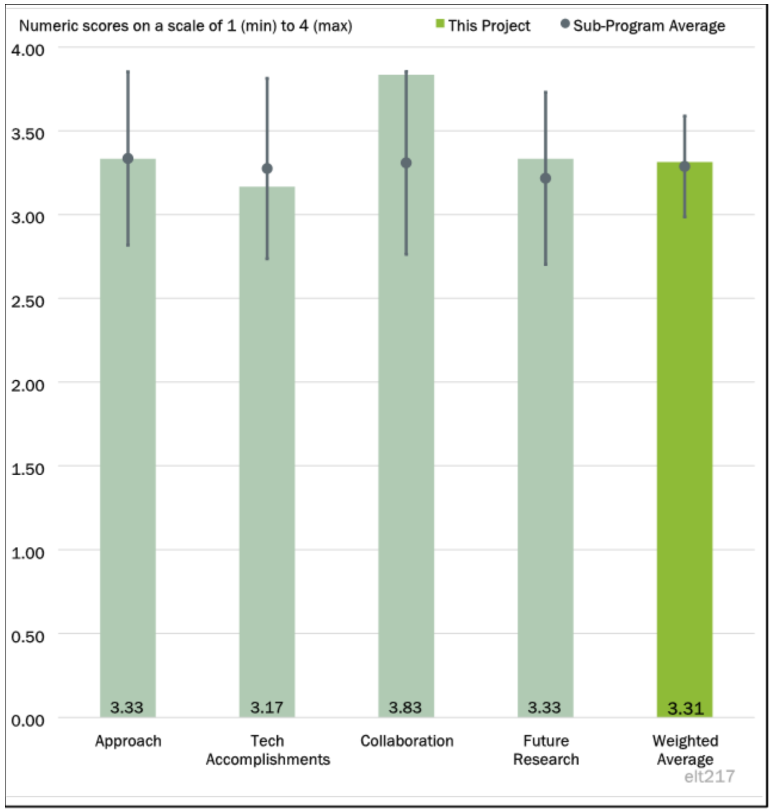

Figure 4-11 - Presentation Number: elt217 Presentation Title: Integrated/Traction Drive Thermal Management Principal Investigator: Bidzina Kekelia, National Renewable Energy Laboratory

Presenter

Bidzina Kekelia, NREL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said using a common cooling structure for the motor and inverter is indeed a step towards integrated traction drive for vehicles. A single fluid which is electrically insulated and thermally conducting could be quite helpful for simplifying integrated traction drive, where the inverter and motor are integrated together.

This reviewer raises concerns related to cooling fluid leaks that could occur under drive system enduring unwanted vibrations faced by the integrated drive system deployed in vehicles. Also, there could be manufacturing challenges and that could come with supply chain related challenges and end users may never be able to overcome these challenges, resulting in no or limited commercialization of technology under development through this project.

Reviewer 2

Generally, the approach makes sense to this reviewer. The thermal management system (TMS) design for the stator windings and power electronics inside the hollow area is complete. However, when integrating the manifolds and cooling channels, there are still some underlying risks like coolant leakage, imperfect contact between T-shape heat exchanger and windings, high pressure drop, etc. These risks can be addressed with hardware iteration.

Reviewer 3

The reviewer said the team uses a T-shape heat exchanger buried between windings to dissipate heat, and a single integrated cooling loop for motor and power electronics. It is an innovative idea. The reviewer suggests the team compare the cooling performance of this design to the traditional end-winding dripping cooling. Although the T-shape heat exchanger is built of material with high thermal conductivity, the air gap between the winding and the heat exchanger still presents a high thermal resistance. Therefore, the reviewer is concerned this design might not have better performance than the traditional end-winding dripping cooling, where automatic transmission fluid directly contacts the winding. If the cooling is not more effective, it would be difficult to meet the power density target for the motor/drive system.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer said the team's FY's 2022's goal is to manufacture and test subcomponents of the integrated machine and drive cooling system by September 2022. The design is completed and manufacturing is on-going. Overall, the project is on track in terms of schedule.

Reviewer 2

The reviewer remarked the concept of the integrated drive system has been evolved including T-shaped heat-exchanger. The T-shaped heat-exchanger will be inserted in motor windings and will transport coolant back and forth from manifold disk. The manifold disk will have O-ring type sealing to prevent fluid leak to power-electronics in motor interior cavity. All these concepts are very well evolved along with completion of some computational fluid dynamics investigations. The reviewer noted the rest of tasks are tracking well including milestone due on 9/30/2022.

Reviewer 3

The reviewer remarked without experimental testing, many of these issues cannot be evaluated. The hardware build is a little lagging behind. This is the fourth year. However, no experimental results or samples are discussed. There might not be enough time left for one more iteration when any issues are found.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer remarked all project partners, drawn from ORNL, NREL and the University of Wisconsin-Madison, are collaborating well.

Reviewer 2

The reviewer said collaboration inside and outside the Electric Drive Technologies (EDT) consortium look good. Electrical machine design as well as integrated motor drive design are making progresses owing to the support from NREL.

Reviewer 3

The reviewer said the team's collaboration is well coordinated.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said future work is clearly stated in the project report with research tasks identified for each project partners.

Reviewer 2

The reviewer is okay with the three specific tasks of building components. Maybe, add a plan for subsystem thermal performance testing before integrating them as the final TMS.

Reviewer 3

The reviewer said the project clearly defined a purpose for future work, but the team is encouraged to demonstrate more data (simulation or/and testing) in the coming quarters to show the performance of the new cooling system and as compared against the traditional traction machine and drive thermal management system.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer affirmed the project supports VTO's goal of more compact electric drive system.

Reviewer 2

The reviewer said this keystone project supports DOE-EDT consortium members by collaboration among DOE labs (ORNL and NREL) and University of Wisconsin-Madison. Project activities will eliminate cost, power-density barriers faced by state-of-the-art electric drives presently used in vehicle while achieving reliability (300,000 miles) and lifetime (15 years) targets.

Reviewer 3

The reviewer noted this advanced TMS design project is of paramount importance for high performance electrical machine system design. So, it is absolutely relevant to VTO goals and scopes.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said the project has all necessary resources including engineering and technical expertise.

Reviewer 2

The reviewer noted that NREL has abundant experience with innovative TMS design. It has good connections with vendors that can provide support. The reviewer did not see any issues in terms of resources.

Reviewer 3

The reviewer said the team has excellent resources to conduct the research.

Presentation Number: elt218
Presentation Title: Advanced Power Electronics Designs-Reliability and Prognostics
Principal Investigator: Doug DeVoto, National Renewable Energy Laboratory

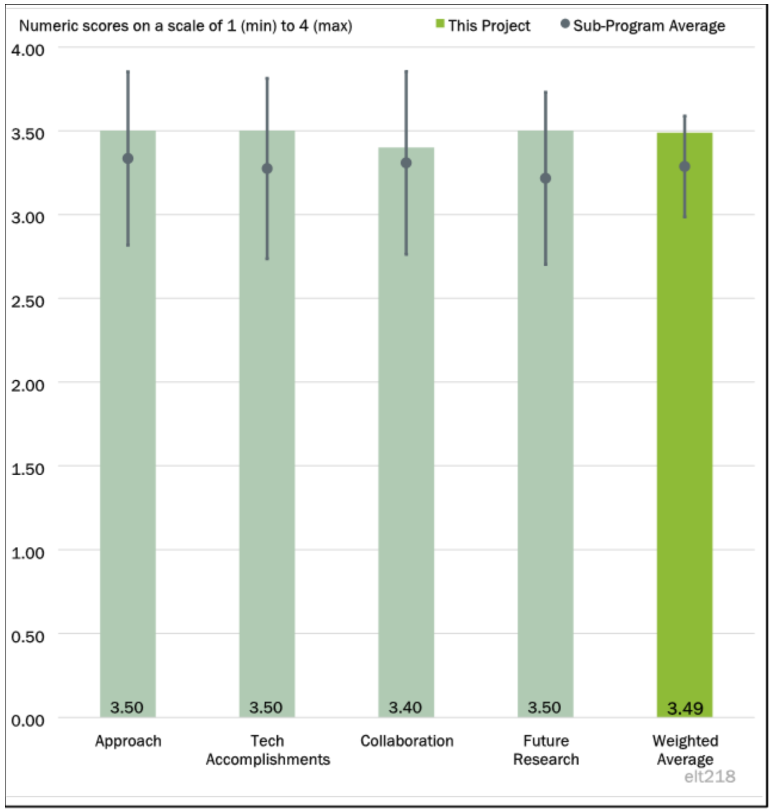

Figure 4-12 - Presentation Number: elt218 Presentation Title: Advanced Power Electronics Designs-Reliability and Prognostics Principal Investigator: Doug DeVoto, National Renewable Energy Laboratory

Presenter

Doug DeVoto, NREL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

80% of reviewers felt that the project was relevant to current DOE objectives, 20% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer remarked the project addresses materials-related aspects of WBG devices by studying a unique approach for more robust mechanical design. The project addresses fundamental questions that need to be answered to enable device development. Like some of the other related projects, involvement of a manufacturer that makes these devices would be very helpful.

Reviewer 2

The reviewer said the team has a clear, well-thought approach to the project.

Reviewer 3

The reviewer said the project team is using a well-known industrial process in packaging of WBG power devices using organic direct-bond copper (ODBC). This could positively impact commercialization of these devices. Additionally, using ODBC allows higher operating temperature while eliminating issues related to hot spots led by high heat fluxes, which could lead to a reliable system level power conversion solution. The reviewer noted this project aims to address thermal and reliability concerns by designing new packages of WBG devices followed by evaluation of WBG power devices under accelerated condition to assess reliability and durability needed in a real-word application of these devices.

Reviewer 4

The reviewer said this project has identified a very important bottleneck in power electronics miniatuirzation and correctly addressed that through discovery and application of new materials and processes.

Reviewer 5

The reviewer remarked program level requirements are never defined. Design and testing targets for the performance and reliability of the bonding and material solutions are not well understood. The reviewer said the PI mentioned that "new package designs must overcome thermal and reliability concerns", why is this necessary? The reviewer struggles to understand why this project is important. Why do we care?

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer said the project team has made excellent progress and is on track to deliver milestone.

Reviewer 2

The reviewer said excellent progress in testing new materials for WBG and developing designs and methods for employing them in WBG devices.

Reviewer 3

The reviewer said excellent technical accomplishments were made on the feasibility of new design and materials use.

Reviewer 4

The reviewer remarked the team has accomplished a great deal on thermal characterization of the insulated substrates.

Reviewer 5

The reviewer commented the bonding and material development accomplishments that are performed by the project are well documented. Is the test plan defined on Slide 9 the de facto testing requirement to be used for all component solutions?

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said excellent partners for the team.

Reviewer 2

The reviewer noted that NREL is closely working with ORNL and industry partners to evaluate new packaging materials and manufacturing techniques for WBG-based traction inverters. In the project Indiana Integrated Circuits (IIC) is supporting/providing chip-to-chip edge interconnection for these devices using IIC's quilt packaging technology. The reviewer noted that DuPont's ODBC substrate is used to replace ceramic substrate. Therefore, collaboration among various entities in the project team is as expected for successful completion of this project.

Reviewer 3

The reviewer said contributions from partners are well integrated, though collaboration would be improved with a device manufacturer. Does IIC fit the bill? The reviewer is under the impression their main contribution is the direct-interconnect method.

Reviewer 4

The reviewer would like to see more documentation and discussion about partners efforts on the collaboration slide.

Reviewer 5

Team has outstanding collaboration network between material, design and process.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer remarked the project has outlined excellent future research and path forward.

Reviewer 2

The reviewer remarked valid and necessary points for follow up work.

Reviewer 3

The reviewer said next steps are appropriate.

Reviewer 4

The reviewer said future research tasks are stated out in the project report and will support project objectives.

Reviewer 5

The reviewer was unclear if the team plans to fabricate the double-side-cooled half-bridge modules in house or subcontract it out.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer noted that WBG power devices with improved packaging are needed to meet DOE ELT 2025 targets including 300,000 miles and/or 15 years life reliability while meeting 100 kW/L power-density and $2.7/kW cost targets. ODBC-based WBG power devices packaging technology fulfill DOE ELT 2025 objectives.

Reviewer 2

The reviewer said this project supports fundamental work needed to advance WBG power electronics and their performance benefits for EV performance (higher range due to improved efficiency, mass reduction).

Reviewer 3

The reviewer affirmed yes, the work is critical for DOE VTO to achieve its objectives.

Reviewer 4

The reviewer cannot determine if the project supports the overall VTO objectives because they are never listed in the presentation. I suspect that these advances are necessary for future power electronics componentry due to down sized package limits and higher power levels, but that understanding is never proven in the presentation.

Reviewer 5

The reviewer said as commented earlier, this project targets to resolve extremely critical issues for power electronics miniaturization.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said resources appear adequate.

Reviewer 2

The reviewer said sufficient, unless the yield of module fabrication is too low.

Reviewer 3

The reviewer remarked the project team has all necessary resources and excellent know-how on background technology that is necessary for successful completion of this project for ODBC-based high reliability and thermal performance WBG power devices.

Reviewer 4

The reviewer said this project has sufficient resources.

Reviewer 5

The reviewer said resources are okay.

Presentation Number: elt221
Presentation Title: Integrated Electric Drive System
Principal Investigator: Shajjad Chowdhury, Oak Ridge National Laboratory

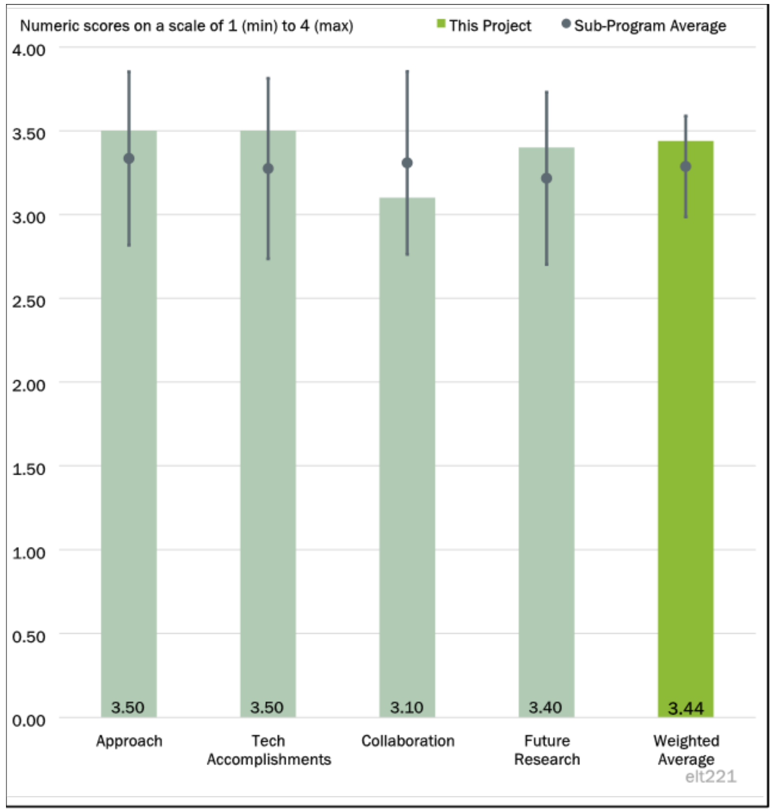

Figure 4-13 - Presentation Number: elt221 Presentation Title: Integrated Electric Drive System Principal Investigator: Shajjad Chowdhury, Oak Ridge National Laboratory

Presenter

Shajjad Chowdhury, ORNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said the approach is well-planned.

Reviewer 2

The reviewer noted that technical barriers namely space and thermal constraint have been correctly identified in this project and addressed as per initial design.

Reviewer 3

The reviewer said good approach, although more discussion next year about milestones would be interesting, and requirements are tied to program goals.

Reviewer 4

The reviewer said the integrated machine and drive with shared TMS is promising for high-power density design. Outer rotor, surface-mounted PM, and fractional slot concentrated windings are helpful for achieving high torque design. The only concern the reviewer had is that this type of machine (outer rotor, surface-mounted PM, and fractional slot concentrated windings) is barely used in traction applications due to high losses, limited maximum rotating speeds, and high magnet usage.

Reviewer 5

The reviewer said the substrate heat spreading study regarding insulated metal substrate with thermally annealed pyrolytic graphite (IMSwTPG) seems like a bit of a distraction because there seemed to be no clear plan or path to fabrication of this substrate based on comments from the speaker during the presentation. Thus, it might be better to focus more clearly on the remaining challenges and work for FY 2022.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer commented technical accomplishments are progressing and on track.

Reviewer 2

The reviewer said the project accomplishments are nice. The capacitor study in particular is well conceived and the results are informative and interesting and show the benefit of the packaging approach.

Reviewer 3

The reviewer remarked the team has accomplished several technical milestones specially around capacitor design and characterization.

Reviewer 4

The reviewer said good work, and I would appreciate a summary of accomplishments at the end of the presentation.

Reviewer 5

Regarding technical accomplishments, the reviewer had the following four comments: First, regarding TMS design, it is not immediately clear that motor stator losses are considered. Or, it is just for PEs. The impression is that the thermal management system is not sufficient for both EM and PE. Second, regarding circular package: the temperature of the capacitors in the inner circle cannot be seen. Highest temperature is expected to be seen there (Slide 9). Third, bearing price and maximum speed are not explained. Also, bearing inner surface (85C coolant) could be warmer than outer, which might result in mechanical tolerance/alignment, and extra losses issues. Fourth, after installation, how easy/hard can we replace and fix modules when there is a failure?

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said collaboration is on track.

Reviewer 2

The reviewer said collaborations look good. NREL takes care of TMS, SNL is providing WBG devices, and Ames National Laboratory is developing advanced magnetic materials. These are the three important areas for this project.

Reviewer 3

The reviewer said the project has a very good design of the collaboration scope. However, it would be good to see how is that being included in the test design in more detail, especially around experimentation on thermal characterization with NREL.

Reviewer 4

The reviewer was unclear how the Ames National Laboratory work fits into the project.

Reviewer 5

The reviewer said the broader aspects of ELTt221 in the context of the larger collaboration were touched upon but were not a major part of the presented work.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said it is critical to overcome the thermal challenges with substrates.

Reviewer 2

The reviewer said good list of future activities.

Reviewer 3

The reviewer remarked the project team has righty identified future research.

Reviewer 4

The reviewer recommended doing some level of subsystem testing involving TMS design as soon as possible. Cooling performance is a huge unknown at this point.

Reviewer 5

The reviewer said the role of the substrate heat transfer study in informing future work was not clear and could be improved.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said an important work toward improving the overall performance.

Reviewer 2

The reviewer said yes, the machine/drive integration theme is highly relevant for future electrified powertrain development.

Reviewer 3

The reviewer said well-defined requirements and goals, as well as on the summary slide.

Reviewer 4

The reviewer noted the project is addressing VTO targets on energy and power density.

Reviewer 5

The reviewer said this project supports the overall VTO subprogram objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said resources are on track.

Reviewer 2

The reviewer remarked resources are sufficient for the proposed FY 2022 work.

Reviewer 3

The reviewer said the future scope of this work is properly identified; however, targets are very aggressive and the project may need additional resources.

Reviewer 4

The reviewer said the team is pretty strong, though there may be a lack of an industry partner. And, that is why the machine design (FSCW-SPM) is not similar to the mainstream of EV powertrain products.

Reviewer 5

The reviewer said resources are difficult to judge because the total project budget is never listed.

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, EPRI

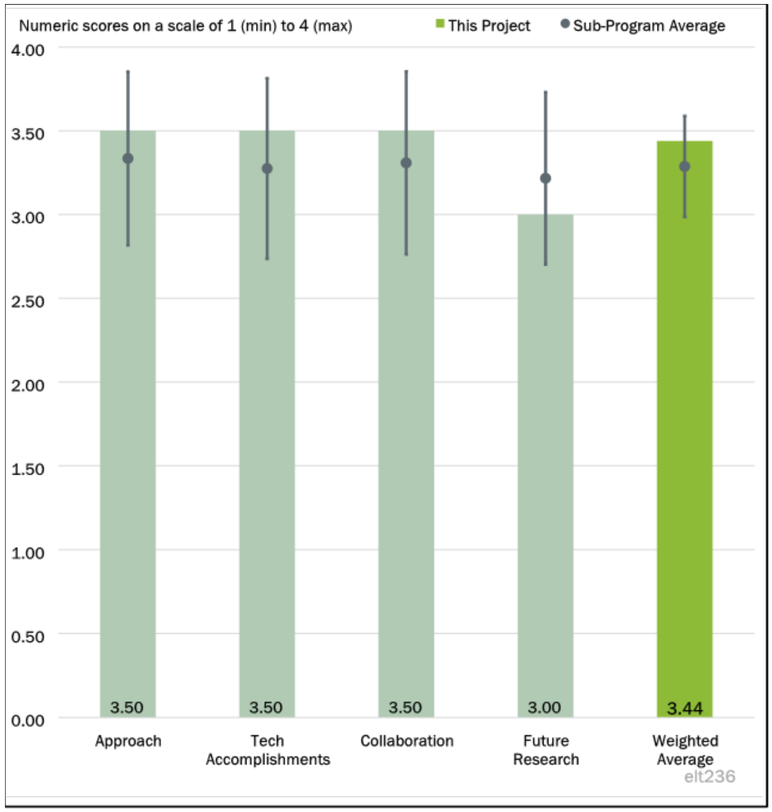

Figure 4-14 - Presentation Number: elt236 Presentation Title: Direct-Current Conversion Equipment Connected to the Medium-Voltage Grid for Extreme Fast Charging Utilizing Modular and Interoperable Architecture Principal Investigator: Watson Collins, EPRI

Presenter

Watson Collins, EPRI

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said the project is well designed with the appropriate teaming strategy and technical barriers addressed. This project is relevant for future EV charging infrastructure needs.

Reviewer 2

The reviewer remarked the project is well defined and the timeline is reasonable. Contingencies are in place to address potential testing site and vehicle availability issues.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer commented the project appears to be on schedule.

Reviewer 2

The reviewer said overall, good progress. Need a little more explanation why the utility interconnection interface is delayed, because this is an important aspect.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said this is a good team with OEMs, national labs, universities, charging companies, and utilities, and all seem to be contributing.

Reviewer 2

The reviewer remarked strong collaboration among project team members has been demonstrated with specific contributions from industry.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said proposed future work supports application, industry, and fleet needs.

Reviewer 2

The reviewer remarked the identified opportunities are all important, but the project is missing a crucial component: economic analysis and cost benefit evaluation.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said this project supports and aligns very well with the ELT subprogram objectives.

Reviewer 2

The reviewer said the project is relevant in supporting the VTO program and DOE goals.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said the project appears to be sufficiently resourced and on track to complete the project.

Reviewer 2

The reviewer commented the resources dedicated to the project are in line with other efforts to support fast charging applications.

Presentation Number: elt237
Presentation Title: Enabling Extreme Fast Charging with Energy Storage
Principal Investigator: Jonathan Kimball Missouri S&T

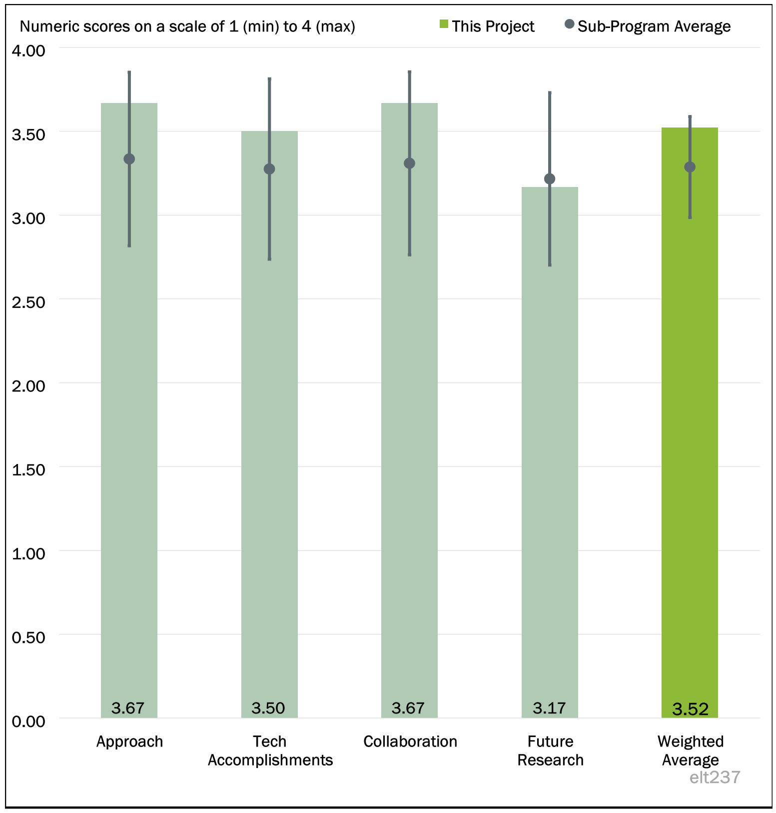

Figure 4-15 - Presentation Number: elt237 Presentation Title: Enabling Extreme Fast Charging with Energy Storage Principal Investigator: Jonathan Kimball Missouri S&T

Presenter

Jonathan Kimball Missouri S&T

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer remarked the project has been phased by design and simulation leading to full scale system development and finally to system test and evaluation. This approach has proven effective in moving the project through budget period 1 and its objectives and well into budget period 2.

Reviewer 2

The reviewer said the project aims at developing the technology for EV charging station allowing rapid charging and minimum impact on grid and on battery. The project has four pillars covering both the grid side and the vehicle side: DC-DC power converter, charging algorithm, grid analysis, and battery pack on vehicle. The reviewer said this comprehensive and wholistic approach is the right approach to answer the need of economical fast charging.

Reviewer 3

The reviewer said the objective of mitigating battery degradation is being addressed with a charging algorithm which relies on specific technical data about the battery chemistry. This achieves the objective for this particular project because a battery is being developed for it. However, because battery chemistry is controlled by the vehicle OEM and a charger would presumably service a variety of vehicles, a key objective is not being met for the real world. Additionally, the reviewer would have expected to see some discussion on battery energy storage system (BESS) capacity sizing based on anticipated load, demand charges, availability of solar, and variable electricity rates.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer remarked the team made good progress. There are 4 tasks: power converter; cell/module/pack modeling and charge algorithm; grid analysis; and vehicle pack design. All tasks appeared to be on track. A full-scale power converter, module, and pack level charging algorithm, detailed and practical grid analysis, and vehicle pack design and construction are all complete. The remaining task is system integration and field testing. The project started in 2018. The reviewer said that even with the impact of COVID-19, the team managed to complete about 60% of the task while still having 25% of the project period remaining.

Reviewer 2

The reviewer said the project has a broad set of diverse objectives ranging from power electronics design to pack design and grid integration. Much of the schedule period was spent in budget period 1 doing design and simulation. The full-scale development and testing in budget period 2 will be the real test of how effectively barriers have been addressed.

Reviewer 3

The reviewer remarked the project is approaching its final year with significant work to be done. A stated objective for the period, 'Design and construct full-scale station' is not shown as being complete though the budget period is still ongoing and there is time to finish it.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer commented a diverse set of tasks have been advanced in a coordinated manner across the team to bring the extreme fast-charge (XFC) concept to the point of full-scale evaluation.

Reviewer 2

The reviewer said the Missouri S&T team works with Ameren (investor-owned utility), Bitrode (battery test equipment manufacturer), and LG Energy solution.

Reviewer 3

The reviewer said there appears to be good collaboration between all parties as the PI does not indicate that they are behind. The project completion percentage needs to increase significantly between now and the end of the budget period.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said the proposed work appears to be reasonable.

Reviewer 2

The reviewer remarked system integration and field testing appear to be relatively short in duration. It is not clear that this will decisively demonstrate the new charging algorithm, nor the effectiveness of the energy storage across multiple use cases of varying numbers of vehicles charged and the spacing in time of charge events. The reviewer said a cost/benefit analysis would be most useful to potential commercial adoption of the developed system. Should the new charge algorithm prove to be successful, it should receive investigation on its own.

Reviewer 3

The reviewer remarked there is not enough detail on the poster (perhaps more a limitation of the format). More information on time allowed for testing and type of testing would help. For example, it would be helpful to understand the various conditions/scenarios that will be tested to see how effectively the grid interface algorithm responds to variations from forecast demand.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said EV charging is critical for a sustainable EV growth. The efforts on a new charging algorithm, new design of vehicle pack, low voltage low power and full power prototype, and grid interface for power and energy optimization are all important for improving charging efficiency and lower the cost. The project objectives and activities support overall VTO subprogram objectives.

Reviewer 2

The reviewer said blazing a new trail for infrastructure in the form of an XFC system is relevant in that it reveals unforeseen barriers that must be addressed to make implementation successful. Should the new charge algorithm prove to be successful, it will be a significant improvement in XFC technology and should receive investigation on its own.

Reviewer 3

The reviewer commented the project addresses advances in charging but it could be doing it in a very narrow fashion in two areas: The objectives of minimizing battery degradation can only be met for a specific battery which may not exist in the real world, and there is no discussion on how BESS and solar capacity should adjust based on variability in the cost function.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said the project has sufficient resource to accomplish the planned technical milestones.

Reviewer 2

The reviewer remarked the project has engaged key technical resources in the areas it is developing technology. Their commitment appears to be sufficient as the project in on schedule for full testing in 2023.

Reviewer 3

The reviewer commented the project appears to have appropriate partners and the PI did not express a concern regarding resources.

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

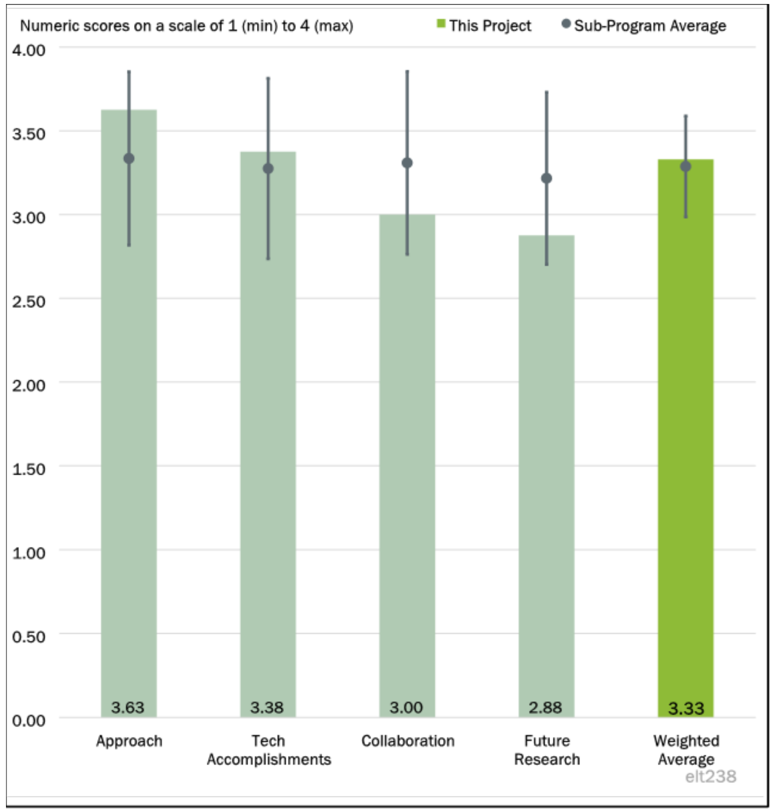

Figure 4-16 - Presentation Number: elt238 Presentation Title: Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State Direct-Current Protection Principal Investigator: Srdjan Lukic, North Carolina State University

Presenter

Srdjan Lukic, North Carolina State University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer pointed out that one technical barrier was a lack of an available energy management platform with the required functionality. The team developed the needed system to demonstrate the system's operations without losing focus on the primary goals of the project. Another barrier, according to the reviewer, was the lack of a domestic provider of a DC/DC EVSE meeting the project's needs, so the team designed, developed, and built a prototype that could be used for the system deployment and testing.

Reviewer 2

This reviewer found that the overall approach to the project is outstanding. It is well designed, though it seems the project is delayed.

Reviewer 3

This reviewer said that the project approach is a very good way to solve an important charging barrier. The project is focused on developing and deploying a 1MW medium voltage XFC station with a shared bi-directional solid-state transformer (SST) connecting to the medium voltage distribution system. Additionally, a

DC distribution network with solid-state DC protection, an energy management platform, and local isolation are being integrated as part of the charging system solution.

Reviewer 4

This reviewer noted that, given the supply chain constraints, a one-year no cost extension seems reasonable.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer said that significant technical accomplishments include: DC solid state circuit breakers (SSCB) have been constructed and tested; SST lab prototype constructed and integrated with SSCB and tested; field SST under construction and first module successfully tested and characterized; final DC/DC stage testing underway.

Reviewer 2

This reviewer found that the team has demonstrated most but not all of the required functionality. Specifically, testing of main source and BESS source faults needs to be completed successfully. On the positive side, the SSCB has achieved coordination in less than 10 microseconds, a 1,000-fold improvement compared to currently available technology and sufficient to realize the overall vision of a charging station with an SST connection to the grid and a local DC distribution network. The project has also achieved impressive functional improvements, achieving 50% or better reductions in volume, mass, and pad size for charger installations, while increasing efficiency from 92% to 96%, i.e., reducing losses by 50% from 8% to 4%.

Reviewer 3

This reviewer said that good progress is being made.

Reviewer 4

This reviewer commented that, given a 1 MW charging approach, the reviewer did not see a reference to CharIN and asked how does this project address current standards development for 1 MW charging.

Additionally, the reviewer asked how the new standards that are being proposed with NEVI funding, including Plug and Charge, are being taken into account? Finally, the reviewer did not see cyber security addressed anywhere in the presentation.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer found strong partnership with contributions from ABB (solid state breaker development and testing), New York Power Authority system deployment and demonstration), and North Carolina State University FREEDM Systems Center (SST and DC Node development and XFC system integration).

Reviewer 2

This reviewer said that excellent collaborations are happening.

Reviewer 3

This reviewer believed that the project team appears to be working well together. However, the team does not include an electric vehicle service provider (EVSP), even though last year's reviewers commented that having an EVSP on the team is important. According to the reviewer, an EVSP is, in fact, critical, because EVSPs are the entities leading the design and construction of charging depots and, thus, the entities that will decide whether or not to implement this technology commercially. The lack of an EVSP's participation was the one major flaw the reviewer found with this program.

Reviewer 4

This reviewer believed that the project could benefit from additional stakeholders, including an EVSE provider, additional utility partners, and an automaker.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer noted that future work of system assembly, integration, and field testing to complete the remaining 20% of the project was appropriate.

Reviewer 2

This reviewer said that the proposed future work, as presented, was exactly right, namely the assembly, integration, commissioning and field testing. While the focus of this project is the technology and field demonstration, a key goal of the VTO is to commercialize technologies, not simply fund "science projects." Accordingly, the future work should include additional analysis of the commercial deployability of the technology. Various barriers, including supply chain barriers, have already been identified, so the team has valuable lessons learned that can be made available to potential users of this technology. This aspect of the future work should also consider manufacturability, which should be readily possible, given that ABB is on the team.

Reviewer 3

The reviewer did not see timelines for the future work. In that sense, the reviewer believed that it could be better defined.

Reviewer 4

This reviewer said that the cost increase and supply chain disruptions are significant. The proposed research is the heart of actually putting the project together for demonstration.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the project is relevant to VTO Grid Integration subprogram as it supports EV extreme fast charging station development with direct connection to the medium voltage distribution network.

Reviewer 2

This reviewer said that the project specifically supports VTO's high-power charging (HPC) objective for 2023, which states, "HPC: Develop strategies and technologies for...multi-port 1+ MW charging stations that enable vehicle charging through direct connection to medium voltage (≥ 12.47 kV) distribution."

Reviewer 3

This reviewer found that the project has strong relevance and supports the VTO subprogram objectives.

Reviewer 4

This reviewer said that the project supports electrification.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the funding seems appropriate—$2.7 million DOE share and $3.3 million contractor share make for a significant project that is addressing an important barriers to enable large scale electrification of the transportation sector

Reviewer 2

This reviewer said that the project team has stayed on plan with respect to budget, though the schedule has been delayed due to supply chain issues. The team will request a one-year extension to make up for the delay, but no additional resources will be requested (or needed).

Reviewer 3

This reviewer believes that the resources appear sufficient, but the PI should address the reasons for the delays, and the timelines for the future/remaining tasks.

Reviewer 4

This reviewer said that sufficient resources for the project exist.

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, ORNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

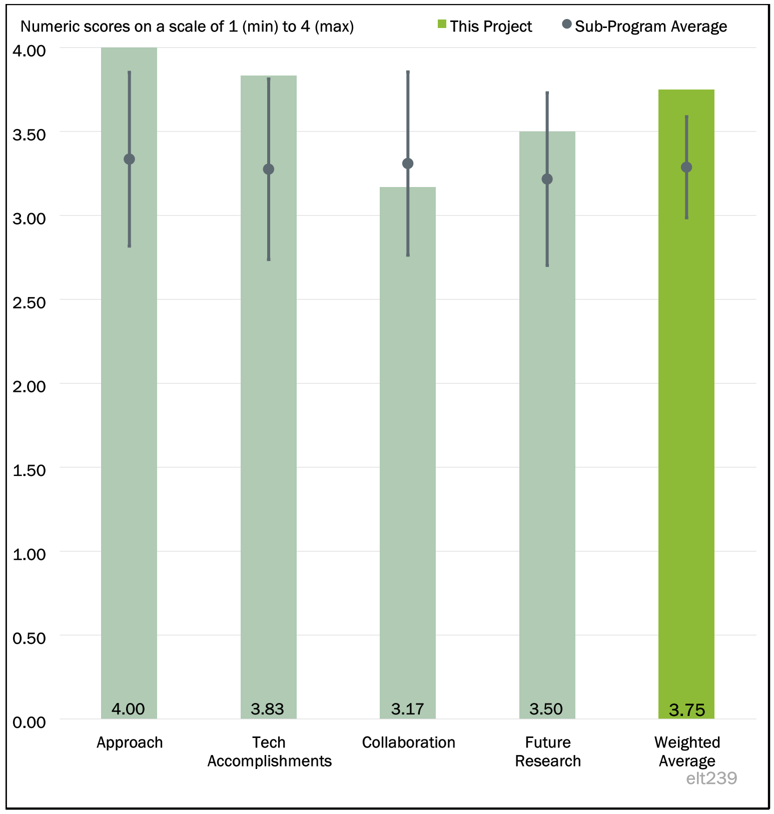

Figure 4-17 - Presentation Number: elt239 Presentation Title: High-Power Inductive Charging System Development and Integration for Mobility Principal Investigator: Omer Onar, Oak Ridge National Laboratory

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that the approach is novel with a modular approach to coil utilization.

Reviewer 2

This reviewer said that the approach seems to be well thought-out, allowing for methodical progress toward project goals. An iterative design appears to have been critical, allowing for development of components and systems in stages, testing, and then redesigning, resulting in a highly effective overall system.

Reviewer 3

This reviewer found that the project team’s approach was to model, test, and validate. The PI explained the design choices on the polyphase coil technology, which generates rotating magnetic fields and allows for a more compact system.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer noted that hardware design has been completed and is going through bench-scale testing. Once done with testing, the demonstration systems (100 and 270 kW) will be hooked up to the test vehicles. Thus, the project seems to be moving along as planned and has completed a large number of activities. The team also appears to have developed a coupler system that has increased surface power density by an order of magnitude over existing couplers. The project's couplers are relatively small and light for transferring high charging rates. The project has also demonstrated 97.4%–98.8% coil-to-coil efficiency, very close to expected levels. Bench-scale testing at the 50kW level demonstrated over 95% overall efficiency. Initial results pointed to a small power loss from the design due to duplication, which pointed to a pathway to redesign to recapture the efficiency being lost. The team also found they can power phases individually, which can simulate a wide range of architectures to match a variety of potential vehicle charging receivers.

Reviewer 2

This reviewer pointed out that the project has several accomplishments. The reviewer appreciated the rotating field video showing the technology developed as part of this project. The design is able to double the effect of output voltage and the team can control phases independently. The polyphase coil is inter-operable with other coil designs, which is important when considering the roadway component. The reviewer also appreciated the size references and comparisons. The operating efficiency achieved is much greater than the required 90%. The project team has taken on an additional challenge of removing the liquid cooling system from the vehicle side to decrease the cost and complexity of EVs.

Reviewer 3

This reviewer found benchmarking, coil design, and technical performance evaluation to be robust.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer pointed out that ORNL is partnered with Hyundai and Volkswagen. While the team does not have an EVSE manufacturer on the team, it does have one that has licensed the technology, though deployment/installation is a few years off. ChargePoint was originally part of the proposal but pulled out. ORNL also indicated that it would be talking with the Electrify America (EA) side of VW to bring in its perspective and knowledge base. EA is interested in offering this system as an option for high-end charging units when the technology is ready.

Reviewer 2

This reviewer believed that the discussions and progress showed that coordination across the team members was good. Cybersecurity is an OEM requirement so the team is addressing it as part of the Electric Vehicles at Scale (EVs@Scale) Consortium. The OEMs also prefer a non-liquid cooling system on the car and the project team is looking at that as well. The team has been getting into discussions with EVSE through VW and HEVO.

Reviewer 3

This reviewer said that collaborator contribution was not highlighted to any great extent.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the project team has clearly identified goals for future research, particularly as related to increasing surface power density even more to accelerate efficiency and thus charging speed. The team is also talking with Stellantis about other future improvements.

Reviewer 2

This reviewer said that the future work is with the OEMs to integrate and demonstrate the system at 100-kW and at 270kW. The 270kW is the limitation of the EV not the charging system. Additional phase systems were discussed and could be possible but more research would be needed.

Reviewer 3

This reviewer believed that the proposed future work is consistent with the project expectations and outcome. The reviewer would have preferred to see more details on future vehicle integration plans.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the work broadly supports vehicle electrification and energy efficiency efforts.

Reviewer 2

This reviewer said that the project is extremely relevant—it is focused on increasing charging rates for EVs to move toward much quicker charging events closer in time to refueling with baseline petroleum fuels. The reviewer believed that that will be extremely important to support greater EV penetrations.

Reviewer 3

The reviewer said that this project supports high-power charging which is needed for a full EV transition in particular with fleet vehicles and those vehicles which are not able to charge in the home or depot location.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the resources appear sufficient based on the outcomes of the project.

Reviewer 2

This reviewer believed that funds appear sufficient for this phase of development and that the team has identified future research needs for additional users.

Reviewer 3

This reviewer found that there were sufficient resources for the scope of this project.

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

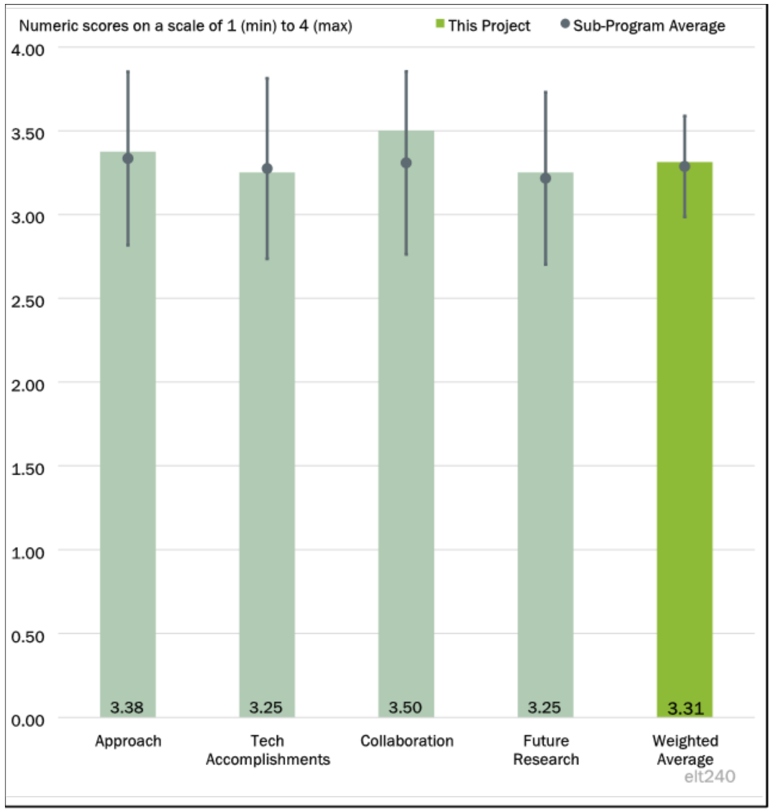

Figure 4-18 - Presentation Number: elt240 Presentation Title: Wireless Extreme Fast Charging for Electric Trucks (WXFC-Trucks) Principal Investigator: Mike Masquelier, WAVE

Presenter

Mike Masquelier, WAVE

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer noted that the project started in 2018 at the Port of Los Angeles. The budget is $10 million The objective is 20 minute full charge at 500 kW using 4160 volts input for higher system efficiency. The reviewer believes that the technical approach is sound.

Only 1,000 zero emission trucks sold last year out of 275k total HD sales. California needs usable/salable/user-friendly systems with a short wait for charging on return to the port to increase adoption, which this project is intended to help create. The cost is about the same for 250 and 500 kW systems. The reviewer believes that the project seems to be on schedule now after supply delays. It still needs UL compliance.

A full total cost of ownership must be developed but is that in the scope?

Reviewer 2

This reviewer said that the development and demonstration of the hardware looks good, suggesting that the team include use data for improvements in the simulation and virtual development of future system changes.

Reviewer 3

This reviewer noted that the team was able to demonstrate key objectives such as 500kW wireless charging early by using proven components. This is a time-tested approach and reduces development and production risk.

Reviewer 4

This reviewer was concerned that there are indicators that the project timeline has issues since the team is not demonstrating an integrated end-to-end system at the port as originally planned. It has geographically split up the project into non-integrated pieces where the MV conversion is tested in a lab and the charging at the port uses low voltage power to supply the wireless charger.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer believed that, other than supply chain issues, there were no impediments to progress reported. Therefore, according to the reviewer, it must be assumed that the project is running as designed and in the task order originally proposed.

Reviewer 2

This reviewer pointed out that, as mentioned in the oral presentation, with the exception of the MV system demo everything looks to be on time as described in the timeline. The demo of the MV charging system at a separate location should be good enough to prove out any potential efficiency improvements.

Reviewer 3

This reviewer said that good progress has been demonstrated by having both vehicles built and validated at Cummins, with production charging pads installed and the whole system tested. The team appears to be confident in its ability to demonstrate 500kW wireless charging, though work remains to be done on battery thermal management and validation of the charging process at the actual test site.

Reviewer 4

This reviewer expressed concerns that the technical progress of the MV conversion appears to have some weaknesses. According to the reviewer, it appears that, by performing the MV conversion in the lab that the development of the control process that coordinates MV conversion with the wireless charger via vehicles' CAN bus (as shown on the block diagram) will not be developed and demonstrated. Also the PI indicated that the MV conversion lab test will focus on measuring conversion efficiencies, but then indicated that he was unaware of any standards that should determine the requirements and hardware necessary for the MV conversion experiments.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer did not see any additional needs for the project.

Reviewer 2

This reviewer found that the partners are progressing together to complete the system and the demonstration.

Reviewer 3

This reviewer said that there appears to be good coordination between several of the partners that will result in a demonstration at the port.

Reviewer 4

This reviewer believed that progress on the hardware side of the project seems to indicate excellent collaboration. Production level 500kW designs are installed on the test trucks and charging in a test setting has been demonstrated. However, the reviewer was concerned that slow progress on the site may risk shortening the available validation period in the final budget period if anything else goes wrong.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the future work clearly identifies several issues that the original project has not addressed.

Reviewer 2

This reviewer believes that the team should finish the development and do the demonstration rather than waiting to see whether this system operates well and is cost effective.

Reviewer 3

Most of the proposed future research lists items that are past the pre-competitive nature of DOE research. Developing better batteries, optimizing, improving system efficiencies, and lowering costs are a bit generic for proposed project research. Developing thermal materials, which the reviewer agrees is an important need for XFC in projects like this would likely be a different project.

Reviewer 4

This reviewer believes that it is not clear how directly the proposed future work is tied into meeting the goals for this project. For example, a BESS is mentioned to offset time of use (TOU) and demand charges but that is not one of the remaining barriers or objectives for this project. However, battery thermal management is a relevant area and may be needed for this project to meet the key deliverables.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer stated that drayage trucks at zero emissions has been a long standing challenge and this may be the first fully workable system to meet the need, making it very relevant.

Reviewer 2

This reviewer said that the proposed use of this technology in heavy duty and fleet customers is a pathway to quicker deployment of electric vehicle technology. The high speed recharging will improve end user utility for quicker adoption and displacement of GHGs.

Reviewer 3

This reviewer said that the project directly supports VTO subprogram objectives to reduce charging times for HD EVs and increase the efficiencies of EV charging.

Reviewer 4

This reviewer said that the demonstration will address a key barrier of uptime and availability in drayage (and other short distance/high uptime applications such as yard tractors, transit buses) and is therefore very relevant to the VTO objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that, now that delays seem to be under control, the forward effort looks to be sufficient.

Reviewer 2

This reviewer said that the presentation shows the project being on track with the resources assigned. The project is nearing its completion and DOE funding is not the majority. Considering the are seven partners in the research, the resources appear sufficient to complete it.

Reviewer 3

This reviewer said that the project team appears to have the necessary resources.

Reviewer 4

This reviewer said that it appears that the resources provided to the project (e.g., funding and time) have been insufficient to perform an integrated end-to-end demonstration as planned and the team has adapted its approach to match the resource constraints.

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

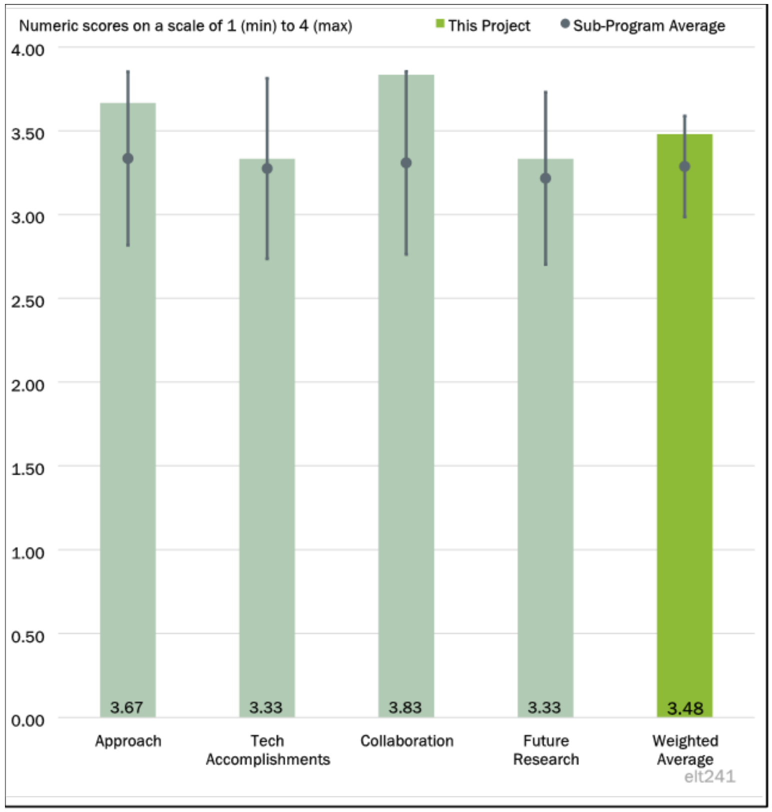

Figure 4-19 - Presentation Number: elt241 Presentation Title: High-Efficiency, Medium-Voltage Input, Solid-State, Transformer-Based 400-kilowatt (kW)/1000-V/400-A Extreme Fast Charger for Electric Vehicles Principal Investigator: Charles Zhu, Delta Electronics

Presenter

Charles Zhu, Delta Electronics

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that the results of the project speak for themselves. The project objectives have been completed, with only further demonstration with various vehicles remaining to be completed.

Reviewer 2

This reviewer felt that the approach (based on the concept and progress thus far) appears effective.

Reviewer 3

This reviewer believed that the overall approach to the project makes sense for achievement of intended goals. The team also designed the system to be highly compatible with renewable energy (solar) and storage, which can also help with demand/grid management.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer said that the work objectives have been achieved with only a small schedule extension resulting from COVID-19.

Reviewer 2

This reviewer said that the project seems slightly behind schedule but not in a major way.

Reviewer 3

This reviewer said that the project has progressed to the point of retrofitting the vehicle. There were some delays due to supply chain and Covid, but the project now seems to be moving ahead. Over the past year, the project did complete testing of the 400 kW/13.2kV unit with five different OEM baseline vehicles (non-retrofitted). Through testing, the team is now anticipating both increased efficiency (by 3%) and smaller footprint (by 50%) than comparable systems. The size improvement will also help future siting of the charging system (such as at conventional fueling stations). Testing has shown 97.5% peak efficiency, vs. a target of 96.5% peak. The team did testing at NextEnergy's site and also developed a second test/demonstration site (American Center for Mobility). Because of the delays, they have requested an extension. The project was scheduled to be completed May 2022, but will now be extended until November 2022.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer found that the collaborative aspects of the project were notable and well described/highlighted.

Reviewer 2

This reviewer noted that the team was large and has been effectively coordinated to build and evaluate both the XFC and multiple vehicles to demonstrate it with.

Reviewer 3

They assembled team was solid, including a vehicle manufacturer, an electronics firm, city/state agencies, a university, and two utilities. It has been working very closely together, focusing the efforts. In particular, GM has worked very closely with the project lead on the vehicle retrofit and NextEnergy provided a test site for the charger with several EVs (including a pre-production Cadillac Lyric provided by GM, plus several available vehicles) in order to show how the charger would be connected to the grid.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the project team clearly identified the work remaining under the project. The principal investigator indicated an interest in looking at a multi-megawatt system for the next project .

Reviewer 2

This reviewer said that the project is 98% complete. The future work is a repeat of the validation work conducted at NextEnergy.

Reviewer 3

This reviewer regretted that greater details on how the minor schedule delay will be addressed through the project extension were not provided.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the project is highly relevant to widespread adoption of EVs.

Reviewer 2

This reviewer said that the project is focused on extreme fast charging, which will be required to allow for quicker (near gasoline-speed) recharging to support greater electric vehicle penetrations into the market.

Reviewer 3

This reviewer said that the project provides a hardware baseline for establishing XFC as a viable strategy for EV infrastructure.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the resources appear sufficient assuming the project extension adequately covers remaining work.

Reviewer 2

This reviewer said that funds appear to be sufficient to complete this phase.

Reviewer 3

This reviewer said that the project is nearly complete and has performed on schedule. This indicates sufficient resources were available.

Presentation Number: elt252
Presentation Title: Wound-Field Synchronous Machine-System Integration toward Increased Power Density and Commercialization
Principal Investigator: Lakshmi Iyer, Magna Service of America Inc.

Presenter

Lakshmi Iyer, Magna Service of America Inc.

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

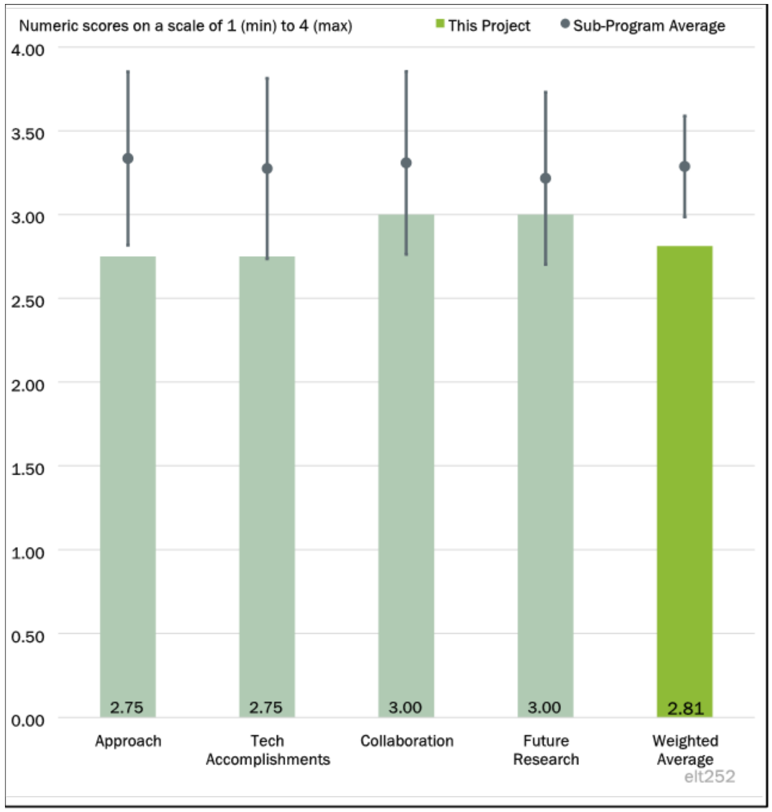

Figure 4-20 - Presentation Number: elt252 Presentation Title: Wound-Field Synchronous Machine-System Integration toward Increased Power Density and Commercialization Principal Investigator: Lakshmi Iyer, Magna Service of America Inc.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that, as non-permanent-magnet machines, wound-field synchronous machines are of interest/importance to industry but, it is not immediately clear how an eight fold increase in power density and nearly 96% efficiency can be achieved with the proposed design. The designs of the stator, rotor and TMS design look like those of a standard wound-field synchronous machine, especially after switching to inductive power transfer.

Reviewer 2

This reviewer said that the approach is very basic and didn’t show a robust process to address the key project objectives

Reviewer 3

This reviewer commented that it is not clear what the key novelties in the project are, aside from optimization and evaluating different fairly standard cooling schemes. The reviewer further noted that the baseline design is not clear and the reference for the eight fold improvement in power density is not clear

Reviewer 4

This reviewer felt that, although the motor design was done systematically the motor's cost assessment does not appear to have been done. Testing to understand reliability/durability has not been included in the project. Both cost and reliability and durability of a technology must be an integral part of the project for a complete technology assessment, according to the reviewer.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

major challenges with the cooling system and with meeting the power levels per the plan

Reviewer 2

(1) Clear quantitative comparison to a well-defined baseline is needed.

(2)Quantification of the impact of the identified limitation of CPT is needed.

Reviewer 3

The level of work given the funding level is solid. Yet the project does not encompass a full enough evaluation to be considered for automotive.

Reviewer 4

Regarding technical accomplishments, the reviewer had the following comments/questions. The multiphysics include electromagnetic design, cooling system (or TMS), mechanical analysis. How many of them are included in the global optimization? The reviewer was not clear how 8X power density and nearly 96% efficiency can be achieved with a standard-looked technology. After switching to inductive power transfer, the reviewer just worries that this project lose one of its major novelties. Finally, some benchmarking will be helpful to understand how it compares to existing products, e.g., GM, BWM or Renault WFSMs. These products are likely optimized as well.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer said that the project is led by industry (Magna) with support from University of Wisconsin-Madison and IIT. This collaboration will make sure that the design is feasible for production. The task assignment also looks good.

Reviewer 2

This reviewer said that there was a good level of collaboration and division of scope among the various partners.

Reviewer 3

This reviewer said that there is reasonable collaboration on the design and planning for manufacturing. But there is a tremendous gap in this project when considering the purpose of the program. Those missing elements would come from greater collaboration with industry.

Reviewer 4

This reviewer expressed a need to see specific actions and results by the partners.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that experimental testing will help verify the analytical predictions.

Reviewer 2

The suggested path forward would be of great interest to this reviewer, noting that taking advantage of GaN device performance attributes could lead to the development of a competitive advantage for industry.

Reviewer 3

This reviewer was satisfied with the prototype build and experimental testing but, suggested that more unique points should be identified for this project, pointing to. “Rectifier board incorporates capacitive resolver” as an example. The reviewer also, requested and explanation of how eight fold power density increase can be achieved here.

Reviewer 4

This reviewer cited a need to outline the plan to achieve the projects targets for power levels and cost.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer believed that achieving the power levels and cost are critical to future applications.

Reviewer 2

This reviewer pointed out that elimination of rare-earth (RE) material is consistent with the DOE targets.

Reviewer 3

This reviewer said that the project’s focus would help develop key technology differences that could be exploited by industry.

Reviewer 4

This reviewer found that this project one is the most meaningful project for industry that the reviewer has seen this year. Wound-field synchronous machines and induction machines are important for traction applications. It is relevant to VTO objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the resources are sufficient for the project scope

Reviewer 2

This reviewer found the resources to be sufficient and did not see any issues.

Reviewer 3

This reviewer suggested that perhaps more resources are needed to address the project plan and goals.

Reviewer 4

This reviewer believed that the scope of this project needs to be broadened to encompass testing over the full operating range. The cost needs to be thoroughly understood for industry to take advantage of the technology

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 four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

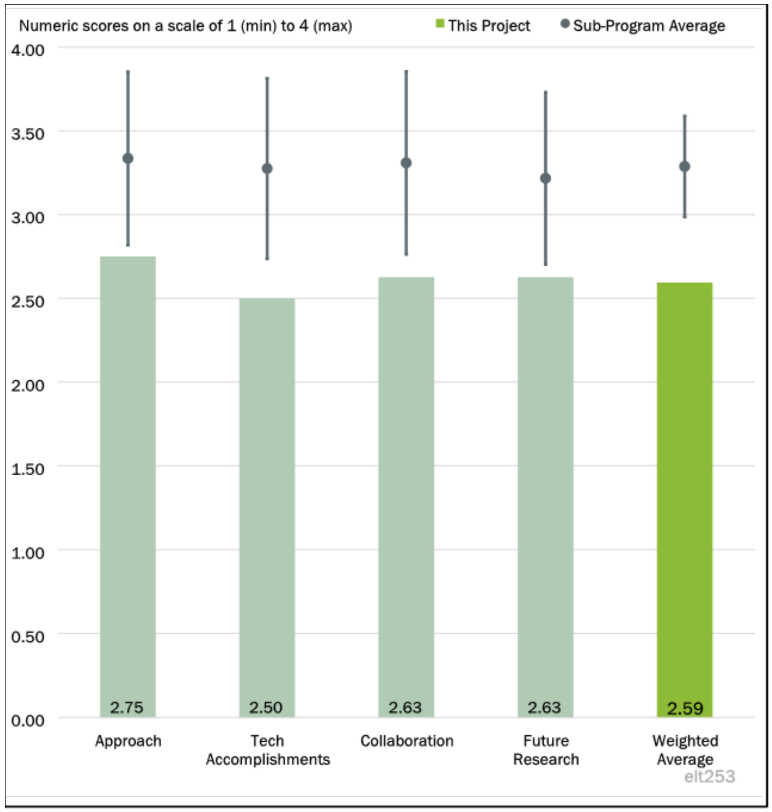

Figure 4-21 - Presentation Number: elt253 Presentation Title: Motor with Advanced Concepts for High-Power Density and Integrated Cooling for Efficiency Machine Principal Investigator: Jagadeesh Tangudu, United Technologies Research Center

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that the overall approach is well designed and on track.

Reviewer 2

This reviewer found that the main novelty seems to be related to the in-slot cooling, the details of which are not very clear, according to the reviewer.

Reviewer 3

This reviewer believed that the project is exploratory in nature only with focus on design and design trade-offs. The reviewer was concerned that no reliability/durability, or detailed cost evaluation is being performed.

Reviewer 4

This reviewer believed that the approach used in this project does not seem to be helpful for the high-specific-power goals, because most likely, a FSCW-SPM machine spinning at greater than 20,000 revolutions per minute requires retaining sleeves, which increase the air gap length and losses. Second, in-slot embedded cooling is only dealing with stator winding losses. There is no plan for stator core, rotor cooling, and power electronics cooling. The reviewer also asked what is the name of the "low loss electric steel" and whether it has lower permeability or higher cost. The reviewer found that the approaches here are very ambiguous.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer believes that the project is on track and expressed interest in seeing the final results.

Reviewer 2

This reviewer said that the work that has been accomplished based on the project plan is good but the project though is too limited in scope to help the auto industry commercialize this technology.

Reviewer 3

This reviewer was disappointed that the details of the analysis performed especially the thermal and structural have not been shared and found it not clear what type of life analysis has been performed.

Reviewer 4

This reviewer said that it is well-known that SPM work is vulnerable under a demagnetizing field and that FSCW machines are prone to loss. In order to accommodate non-heavy RE material, low operating temperatures (less losses/better TMS) and better protection, e.g., using interior permanent magnets (IPM) are required, raising the question for the reviewer of why FSCW-SPM is selected specifically for vehicle powertrain for this project. Further, based on the contents of the slides and giving the fact that it was funded in FY 19, the reviewer had concerns about the project timeline. Although it is claimed that everything is on track, according to the reviewer, many things are missing here: detailed final design, demagnetization analysis, a clear cooling design, etc. The presenter mentioned that there were supply chain issue, shipping and other delays. But, the reviewer asks why other presenters and their projects were not hit so badly. Also, the reviewer found no details (data or figures) about the latest design analysis.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer said that the project is on track.

Reviewer 2

This reviewer said that a vehicle OEM should be added as a participant.

Reviewer 3

This reviewer said that the level of collaboration is not very clear, especially when it comes to the integration details of the motor and inverter,

Reviewer 4

This reviewer said that the team (Raytheon Technologies and John Deere) looks good. But, based on the presentation, the reviewer was not sure what has been really accomplished so far.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the project is in its final phase;

Reviewer 2

This reviewer said that verification testing will help confirm the analytical predictions.

Reviewer 3

This reviewer said that it is not clear from the materials presented what the next steps are, apart from that testing will be completed, and a report filed.

Reviewer 4

This reviewer found that no proposed future research was explained during the presentation.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer found the project to be critical to improving the electrification portfolio for cost and performance

Reviewer 2

This reviewer said that, directionally, a few aspects of the proposed approach can help meet the DOE targets.

Reviewer 3

This reviewer expressed a lack of confidence that this work has enough information points to make it useful for industry.

Reviewer 4

This reviewer said that the project has high relevance to the VTO subprogram objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the project is on track.

Reviewer 2

This reviewer said that the resources are sufficient based on the project scope.

Reviewer 3

This reviewer said that the resources are sufficient for this project.

Reviewer 4

This reviewer said that the project needs to develop a detailed understanding of the technology for it to be useful.

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: Jim Gafford, University of North Carolina at Charlotte

Presenter

Jim Gafford, University of North Carolina at Charlotte

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

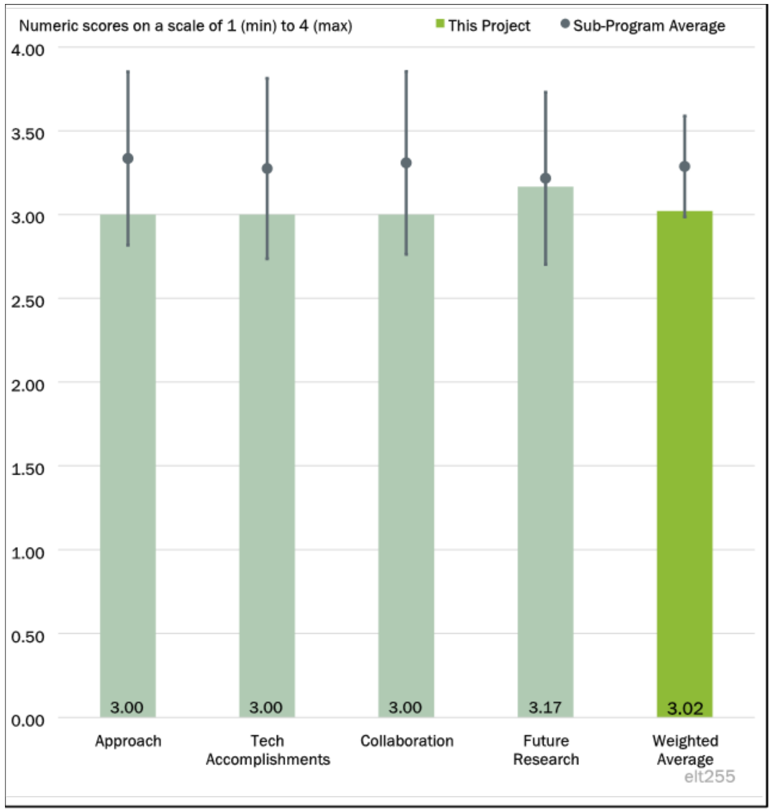

Figure 4-22 - Presentation Number: elt255 Presentation Title: Cost-Effective, Rare-Earth-Free, Flux-Doubling, Torque-Doubling, Increased Power Density Traction Motor with Near-Zero Open-Circuit Back-Electromagnetic Field and No-Cogging Torque Principal Investigator: Jim Gafford, University of North Carolina at Charlotte

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that the approach is well thought out.

Reviewer 2

This reviewer said that the project tasks are appropriate and reasonable. The level of the build and testing to be performed leaves many industry questions unanswered. As an exploratory project, it is a good step forward, but it has major gaps when considering the purpose of accelerating vehicle technology deployment to benefit consumers.

Reviewer 3

This reviewer found that the novelty of the proposed approach is not very clear; even though it was mentioned that an IPM machine was used as a baseline, no details or quantitative comparisons were provided; and the details of what leads to such high inverter power density were not shared.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer found that good test results had been achieved with promising applications.

Reviewer 2

This reviewer believed that, based on the scope of work, the progress has been excellent. This project, however, is missing essential work to provide commercialization value to industry and to overcome barriers, including, for example, the scaling of the motor to traction power level, testing for durability/reliability, and cost analysis.

Reviewer 3

This reviewer considered that, compared to the accomplishments of previous years, the FY 2022 accomplishments seem incremental. More test results and characterization of the motor and inverter are needed.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer said that the collaborators are well respected and are actively participating but would have liked to see a vehicle manufacturer as a partner.

Reviewer 2

This reviewer found the project to be well coordinated.

Reviewer 3

This reviewer found a clear definition of roles among team members.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer expressed interest in seeing the test results of the dynamometers and an economic analysis.

Reviewer 2

This reviewer believed that more test results are needed

Reviewer 3

This reviewer said that the proposed future work, based on the scope that this project has, is reasonable and would be meaningful if the project were followed by more extensive development and testing of the motor.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer believed that the project is critical to improving power density and cost.

Reviewer 2

This reviewer said that, if successful, the project can satisfy some of the DOE targets.

Reviewer 3

This reviewer found that technical relevance of this project exists

But without the further work to understand reliability/durability, full operating testing, and cost analysis, this work will have limited or no commercial opportunity.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer found the project to be on track.

Reviewer 2

This reviewer said that the resources are sufficient based on the project scope

Reviewer 3

This reviewer found that the project itself has merit, but its scope is too limited.

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

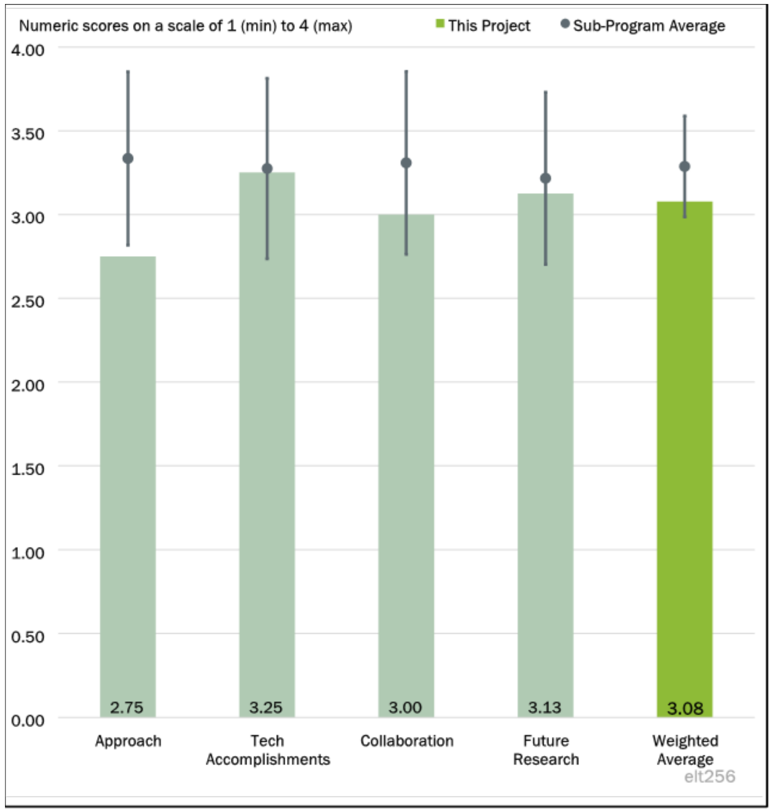

Figure 4-23 - Presentation Number: elt256 Presentation Title: Amorphous Metal Ribbons and Metal Amorphous Nanocomposite Materials Enabled High-Power Density Vehicle Motor Applications Principal Investigator: Mike McHenry, Carnegie Mellon University

Presenter

Mike McHenry, Carnegie Mellon University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer believes that the project is systematically addressing the open questions.

Reviewer 2

This reviewer commented that material suppliers/developers should be included as partners in this as well.

Reviewer 3

This reviewer found that the barriers and technical targets listed on Page 2 are inadequate. There is no definition or explanation of the targets; just a litany of topics that are developed further within the presentation. The reviewer found it unclear whether the timeline is reasonably planned since no time plan for work is shared other than a high level review of a couple milestones. Furthermore, according to the reviewer, the listing of future work would indicate that the project will not be completed.

Reviewer 4

This reviewer found that the baseline used to claim an eight-fold improvement in power density is not suitable for traction applications; the assumed very high switching frequencies do not take into consideration the impact on the motor insulation life; and the proposed motor topology is fairly complicated and will end up being an expensive option.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer said that the project has achieved all technical milestones and made very good progress towards solving the main challenge.

Reviewer 2

This reviewer said that the progress has been systematic, addressing manufacturing and analysis of sample material for performance and mechanical properties.

Reviewer 3

This reviewer said that the specific accomplishments for the worked performed is detailed well. The manufacturing slides provide especially good insights. The reviewer believed that it would be helpful if there were an explanation or discussion of how the accomplishments would specifically lead to the desired motor performance including how the FEA proves motor success? The reviewer found it unclear on Slide 18 if the stress calculations indicate that the motor will fail and asked what is the backup plan if it were to fail.

Reviewer 4

This reviewer suggested that a quantitative comparison of the proposed motor performance, including the AMR, against a well-defined set of specifications or baseline for traction applications should be included.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer found a very good listing of collaboration partners and the work performed but asked whether the North Carolina State University motor testing will be completed in time.

Reviewer 2

This reviewer found great collaboration, but would have preferred to see a vehicle manufacturer involved.

Reviewer 3

This reviewer said that, while the designed collaboration has really worked, the scope needs to be broadened to include metal alloy suppliers, epoxy suppliers and other material chemistry developers.

Reviewer 4

This reviewer said that there seems to be a good level of collaboration among partners.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer found that the proposed future research is clearly outlined with actionable steps and path forward.

Reviewer 2

This reviewer believed that the project has an excellent plan.

Reviewer 3

This reviewer said that more comprehensive motor performance verification testing is needed.

Reviewer 4

This reviewer believed that more future work challenges should have been listed and asked: 1) Why a roadmap of standard safety factors is needed for completion of this project; and whether the testing at NC State will correlate FEA and tensile strength results to actual motor performance.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that improved soft magnetic materials can be helpful in meeting the DOE objectives

Reviewer 2

This reviewer believed that it is important to research these materials and show how they can be successfully manufactured to achieve VTO motor objectives.

Reviewer 3

This reviewer said that materials are critical to meeting DOE targets.

Reviewer 4

This reviewer said that the project will help meet energy efficiency targets.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the project is properly resourced.

Reviewer 2

This reviewer would have liked to see follow-on work sponsored for commercialization.

Reviewer 3

This reviewer was unable to determine this, saying that the budget for the project was not listed.

Reviewer 4

This reviewer said that budget information was not included.

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

Presenter

Andrew Meintz, NREL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

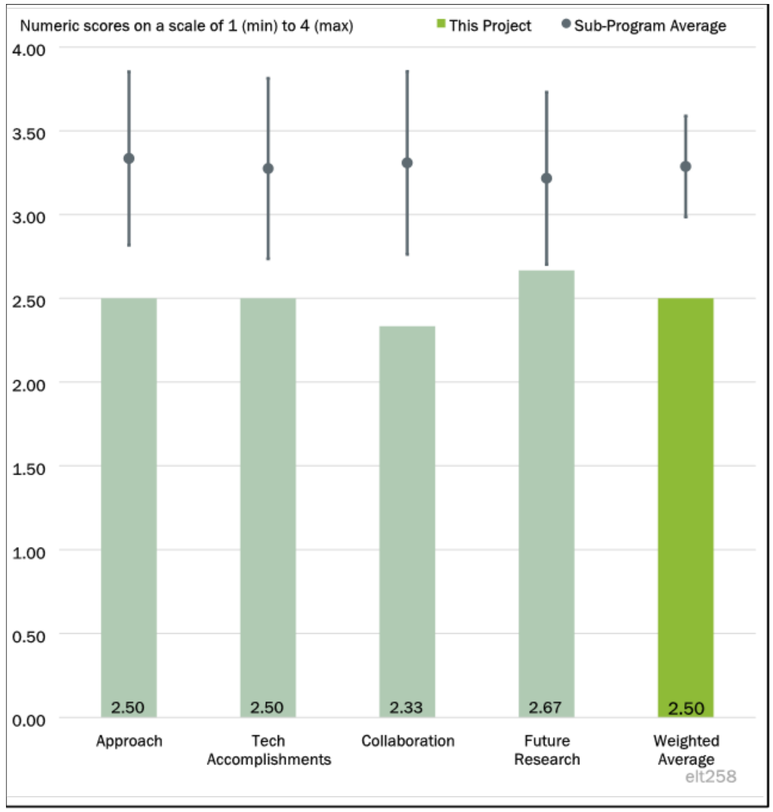

Figure 4-24 - Presentation Number: elt258 Presentation Title: Grid-Enhanced, Mobility-Integrated Network Infrastructures for Extreme Fast Charging (GEMINI-XFC) Principal Investigator: Andrew Meintz, National Renewable Energy Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

This reviewer said that the technical barriers are identified and the timeline is reasonable. However, it is not clear how simulations only will truly address the technical barriers. The modeling data need to be compared against real data.

Reviewer 2

This reviewer found that, because the project focus is on one densely populated area, it is not clear how the data apply to other locations. This study is based on SFD and MUD and the majority of use is AC L1. There are no data on commercial use of XFC that will certainly not have this proportion of AC L1.

Reviewer 3

This reviewer said that no information was provided in the presentation on the number of electric vehicles involved, the percentage that were ride-hailing, the percentage of the total charging power demand served by extra fast charging, what thresholds constituted high EV adoption, and other variables. Second, the choice of the San Francisco Bay area to study the interaction between power grid and extra-fast charging infrastructure was poor because it is not representative (i.e., typical) of most U.S. cities. San Francisco and the Silicon Valley are geographically isolated because they are on a peninsula accessed by bridges and ferries, which constitute traffic bottlenecks. Also, transit usage is high in San Francisco and there is a reverse commute that prevails between San Francisco and the Silicon Valley (San Jose, Santa Clara, Milpitas, etc.).

The definition of the objective, “Identify how XFC will support transportation with evolving mobility patterns and very high EV adoption levels” is very ambiguous, so it is difficult to determine accomplishments. Likewise, the same applies to “As impacts of widespread uncoordinated XFC of passenger vehicles on distribution networks.”

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer said that the project appears to be on track with its plan.

Reviewer 2

This reviewer believed that the technical accomplishments and progress thus far are unimpressive. According to the reviewer, the data collected do not make a bit of difference in what we already know: that coordination will be required among the charging infrastructure, grid, and vehicles. It is sad to see only six months devoted to the control strategies for coordination because this coordination is the strategic centerpiece of the entire project and what makes this project worthwhile.

Reviewer 3

This reviewer stated that commercial vehicles that have local routes along with other vehicles passing through need to be evaluated for XFC in this project.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer pointed out that the team is comprised of only national labs. Since the team was modeling a specific geographic area it should have included the electric utility serving that area. Further, it should have included fleet operators since they would be the most likely to change behavior based on signals.

Reviewer 2

This reviewer stated that the milestones need to show what NREL and Lawrence Berkeley National Laboratory is performing. These roles are not identified.

Reviewer 3

This reviewer felt that collaboration and coordination across the project team was extremely limited and thus, disappointing; it was limited to the national laboratories. No other public or private organizations were incorporated as partners. Unfortunately, organizations involved in traffic modeling, such as the metropolitan planning organization (the Metropolitan Transportation Commission) for the San Francisco Bay area were not made partners and neither was a utility (such as Pacific Gas and Electric) made a partner.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer suggested that an economic analysis should be included, particularly if infrastructure upgrades are evaluated.

Reviewer 2

This reviewer said that the focus needs to include EV's with longer range, that may not charge as often. Including light-duty and commercial vehicles data in Sept 2022 will also change the results and should provide a more complete analysis of XFC requirements.

Reviewer 3

This reviewer noted that the project has only another six months to be completed. The two major tasks that are remaining are coordination and control strategies in Hierarchical Engine for Large-scale Infrastructure Co-Simulation (HELICS) and assessment of impact on distribution networks. The principal investigator failed to describe in detail, examples of control strategies, assumptions for control strategies, and the baselines that would be used for control strategies. With respect to distribution networks, the team should have clarified in its presentation that these are not city-wide or region-wide distribution networks but on-site distribution networks. The reviewer believed that the assessment of the localized impact on site distribution networks is a trivial, insignificant task or minor detail that could have been deferred or omitted.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the project supports the objectives.

Reviewer 2

This reviewer pointed out that the project team has indicated that passenger cars may use more AC L1 than XFC in highly populated areas but their effect needs to be assessed in other less densely populated cities.

Reviewer 3

According to this reviewer, this project seems relevant to only the area of analysis; it does not have any impact on batteries, electrification, energy-efficient mobility systems and advances in materials. Even in the area of analysis, it seems academic rather than practical.

Most important, the reviewer said, is the fact that the project does not make a cogent case for extra fast charging, especially of electric passenger vehicles. Because the overwhelming majority of electric passenger vehicles are or will be used for commuting between home and work, extra fast charging is unnecessary and can simply be replaced by charging at home, a much more cost-effective option with the least impact on the electric power grid. Ride-hailing electric passenger vehicles and light-duty electric package/delivery vehicles are the most likely sectors to use extra fast charging, but these constitute a minority

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the project should include other partners, particularly entities that would benefit from the model.

Reviewer 2

This reviewer said that the modeling tools are well defined, but it is not clear how to include modeling for extended range cars and added use for commercial vehicles.

Reviewer 3

This reviewer believed that the project costs for modeling are excessive in light of the fact all the models used for this project have been already developed or programmed. There was no need to develop, test and debug new models for this project.

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 four reviewers evaluated this project.

Project Relevance and Resources

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

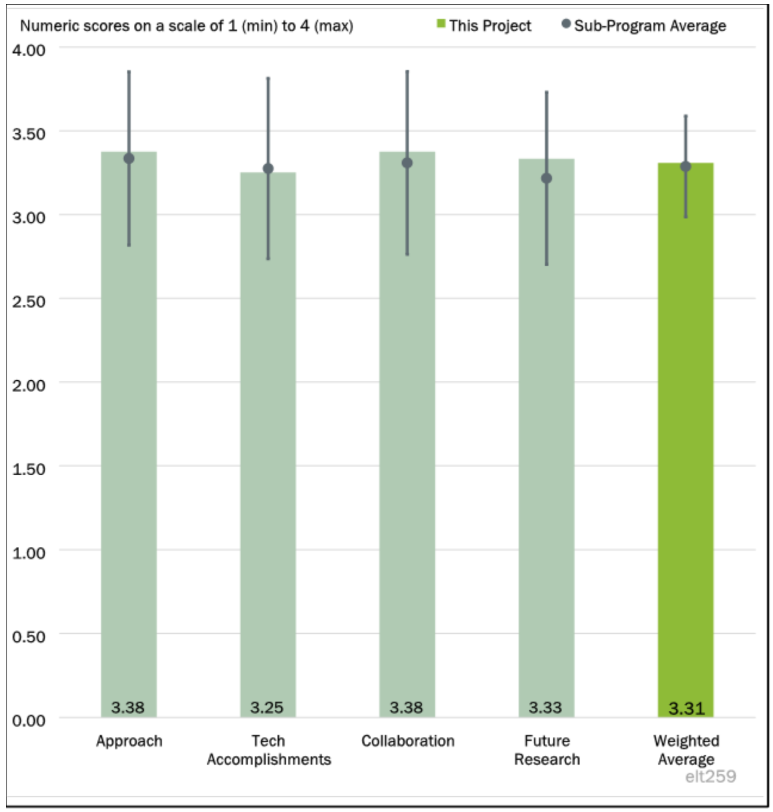

Figure 4-25 - Presentation Number: elt259 Presentation Title: Development and Commercialization of Heavy-Duty Battery Electric Trucks Under Diverse Climate Conditions Principal Investigator: Marcus Malinosky, Daimler Trucks North America

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that the approach is really nice and is looking forward to the additional vehicle deployment testing.

Reviewer 2

This reviewer found the approach to be somewhat difficult to evaluate, since the presentation focused on the managerial details about meeting goals and milestones. One feature that the reviewer thought was especially good was the postulation of several duty cycles that showed how careful scheduling could enable an electric truck to travel many more miles in a day than its range on a full charge. This enabled a sensible design, although the reviewer believes that the cost of a 10,000 lb. battery is likely to make the design somewhat impractical.

Reviewer 3

This reviewer said that the team is doing a good job of making the technology ready for production.

Reviewer 4

his reviewer said that the two barriers that this project intended to overcome were to extend the range for all-electric medium- and heavy-duty trucks to 250 miles per day and to make such trucks viable for manufacture by large volume companies. The project has demonstrated that the range of 250 miles per day has been attained and has started commercial series production this year.

The timeline was reasonably planned. The principal investigator reports that 80% of the work has been accomplished. This is reasonable, considering that this project has a duration of 40 months of which 34 months have passed. So, one would expect that, working at a steady rate, 34/40 or 85% of the project would be accomplished.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer said that the cold weather testing was revealing and important and a big milestone. Final deployment-level testing will be critical to prove every in the end.

Reviewer 2

This reviewer found it impressive that the team managed to remain on schedule and accomplish several builds when others were severely delayed by supply chain problems but that it would have been much more informative if the presentation gave some clue as to the improvements made from Truck A to B to C...

Reviewer 3

This reviewer said that the project showed good progress with one exception. The exception is that it failed to corroborate improved performance over the baseline eCascadia in the following areas: increased fuel efficiency of 2.0 kWh/mile; increased battery capacity up to 550 kWh; and reduced curb weight down to 20,000 lbs. The principal investigator needs to show whether these three objectives, as indicated in Slide 3, were actually accomplished or are still in progress And, if they are still in progress, what is the extent (percentage) accomplished.

Reviewer 4

This reviewer found that the team is doing a good job at meeting the target that has been set, which is a 250 mile range. The reviewer would have preferred, however, for the team to have chosen a more difficult target to meet, i.e., a higher range. Volvo currently offers a tractor with up to 275 miles of range. The reviewer believes that DOE should fund projects that stretch the limits of what is currently feasible, rather than replicate something that is already available.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer said that good collaboration with partners was described.

Reviewer 2

This reviewer believed that the PIs had assembled an excellent team that covered the spectrum of required skills. There was coordination in that the designers had an understanding of the needs of the users before they designed the truck system.

Reviewer 3

This reviewer noted that Daimler has partnered with two end-user entities for fleet operations: Meijer (a grocery store chain in the Midwest) and United Parcel Service and with one regulatory agency: SCAQMD. The two end-user entities are more than qualified to test the operations of the production and demonstration vehicles. SCAQMD is renowned for enforcing rigorous regulatory requirements for medium- and heavy-duty vehicles.

Reviewer 4

This reviewer reported that the partners are ready to put the trucks in the field once they are ready. Not much was shared, however, according to the reviewer, about the partners, since they did not have the trucks yet.

*Question 4: **Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?***

Reviewer 1

This reviewer was looking forward to seeing the remaining results.

Reviewer 2

This reviewer pointed out that the plan is to demonstrate the trucks and collect data to validate the concept. The reviewer expressed interest in seeing a cost analysis as well, including any lost revenues from carrying around 10,000 pounds of batteries.

Reviewer 3

This reviewer believed that an interesting part of the future work should be to gather feedback from the partner organizations who will put the trucks in the field in order to learn and identify potential areas of improvement. The time allocated to that seems limited as trucks are currently being delivered and the project ends by year end.

Reviewer 4

This reviewer pointed out that the project has only six months to complete.

*Question 5: **Relevance: Does the project support the overall VTO subprogram objectives?***

Reviewer 1

This reviewer believes that the project is highly relevant work with potential for major carbon neutral impact.

Reviewer 2

This reviewer said that the project is relevant in that it helps moving towards a decarbonized transportation sector.

Reviewer 3

This reviewer said that this is another project that helps break down barriers to electrification of the entire transport sector, and so is totally in line with the ELT goals.

Reviewer 4

This reviewer said that the project supports the VTO subprogram areas of analysis, battery, electrification, and energy-efficient mobility systems (weight reduction). This project supports the electrification of heavy-duty vehicles, and, thus, reduced reliance on fossil fuels and reduced emission of greenhouse gases. An affordable, commercially available electric-battery medium- and heavy-duty truck is definitely needed to fill a gap in the surface transportation sector.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the resources seem sufficient.

Reviewer 2

This reviewer said that the resources allocated seem appropriate despite the difficulty of judging without any accounting breakdown.

Reviewer 3

This reviewer said that there has been no indication that the project has encountered resource problems. The resource problems are predominantly related to delays due to supply-chain interruptions during the pandemic.

Reviewer 4

This reviewer found that the resources appear sufficient overall. A higher portion of the funding and effort could have been on the analysis of the trucks in the field. As this is a new technology, analysis of field testing should be key to help OEMs make future improvement to their proposed solutions. Documenting field testing would also increase visibility of the technology and help increase customer acceptance.

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

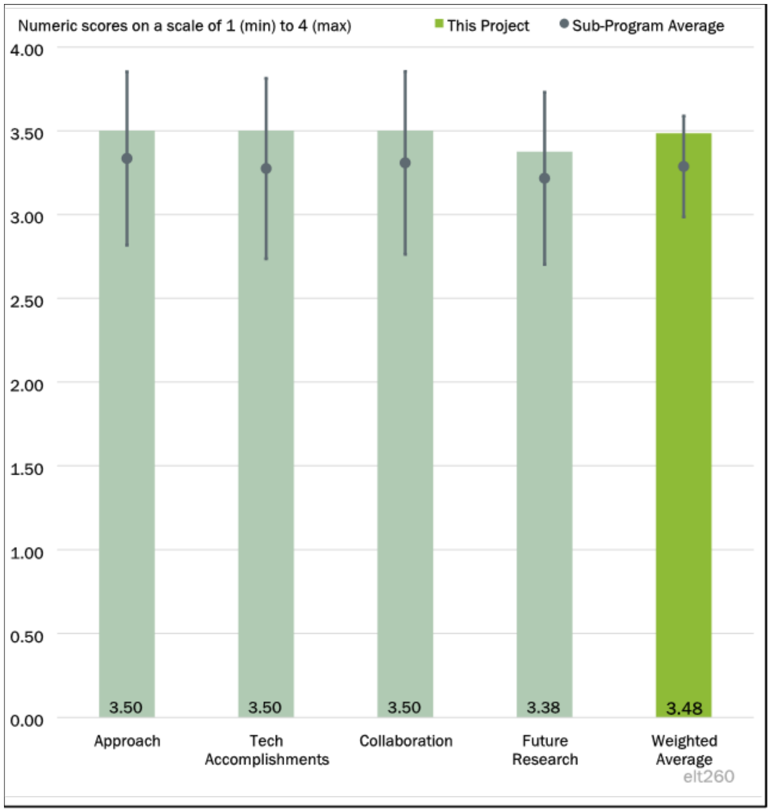

Figure 4-26 - Presentation Number: elt260 Presentation Title: Improving the Freight Productivity of a Heavy-Duty, Battery Electric Truck by Intelligent Energy Management Principal Investigator: Teresa Taylor, Volvo

Presenter

Jian Li, Volvo, and William Northrop, University of Minnesota

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that the project tackles the goal of EV freight energy efficiency with a number of techniques, which is appropriate given the uncertainties involved (load, driver behavior, environmental variability).

Reviewer 2

This reviewer found the three different techniques to estimate mass (detailed to regression) interesting. Load will drive a large charge in vehicle range. Eco routing is likely more important to EVs than to internal combustion engines and this approach to allowing time to be valued along with efficiency (miles kWh) is good for user flexibility.

Reviewer 3

This reviewer found that it is an interesting project with a good approach.

Reviewer 4

This reviewer found it useful to have included some modeling in the effort, but that actual on-road experience is what will really matters. The reviewer has concern that the participants are more interested in using elegant tools than in performance. If preliminary data show that route optimization only results in a few percent savings, perhaps that feature should be eliminated.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer said that several techniques for energy estimation and route selection based on optimal energy consumption have been demonstrated.

Reviewer 2

This reviewer reported having seen very similar math and approaches to eco-routing. This yields its own version and the attribute list looks complete. It would be useful to see a distribution of miles/kWh or similar energy efficiency for all routes and types as the project completes if that information is stored and collected. The reviewer would like to see if there any balance of lost time from having to Eco route trips vs. lost time if routes are not completed from lack of battery energy to complete and if some level of buffer need between eco benefits and time can be determined.

Reviewer 3

Very good progress is being made.

Reviewer 4

This reviewer expressed being a bit concerned about the siting of charging infrastructure. The example in the slides had unconstrained costs. But, in reality, EVSE can be expensive. Since the team is obviously big on modeling and optimization, the reviewer suggests that it consider siting EVSE in the overall most cost-effective way, rather than where it is optimum for the trucks. Getting the trucks to the users was a big accomplishment.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer found excellent collaboration between academic and industrial partners with each doing what it does best.

Reviewer 2

This reviewer was impressed with all of this project’s teams. Each team includes a truck manufacturer, an academic institution to do the hard calculations and analysis, and actual real-world users to demonstrate that all of the calculations and theoretical ideas actually work where the rubber meets the road.

Reviewer 3

This reviewer found nothing to add, saying that the listed partners completed the required tasks as planned.

Reviewer 4

This reviewer said that there is good collaboration amongst the project team members.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the next steps are appropriate for successful demonstration.

Reviewer 2

This reviewer expressed interest in seeing the data at the end of this project. Specifically, the reviewer is interested in whether the trucks meet their efficiency and range goals, how the costs/total cost of ownership will compare to hybrid or other designs, and whether any glitches are observed during operation.

Reviewer 3

This reviewer found the future research plans good

Reviewer 4

This reviewer said that the project does not list any FY2023 funding, but proposed FY2023 work. The proposal looks good as it exercises the tools that were created to create useable data for planning.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the project develops necessary technology to maximize electric truck range, given the challenges of onboard energy storage, making it relevant to the electrification goals of VTO.

Reviewer 2

This reviewer predicted that the project will help prove that electrification of heavy-duty trucks can be a practical reality.

Reviewer 3

This reviewer said that route planning and energy conservation to improve the EV experience fits within the objectives.

Reviewer 4

This reviewer said that the project is very relevant to the overall VTO objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the project appears to be sufficiently funded, with good progress.

Reviewer 2

This reviewer said that the project is listed as completing. Funding and Team Resources are presented as being sufficient to close out or follow-on if new funding is awarded.

Reviewer 3

This reviewer said that the resources appear to be sufficient.

Reviewer 4

This reviewer said that the resource question is very hard to answer without seeing a budget But nothing stands out as unusual.

Presentation Number: elt261
Presentation Title: High-Efficiency Powertrain for Heavy-Duty Trucks using Silicon Carbide Inverter
Principal Investigator: Steve Peelman, Ricardo

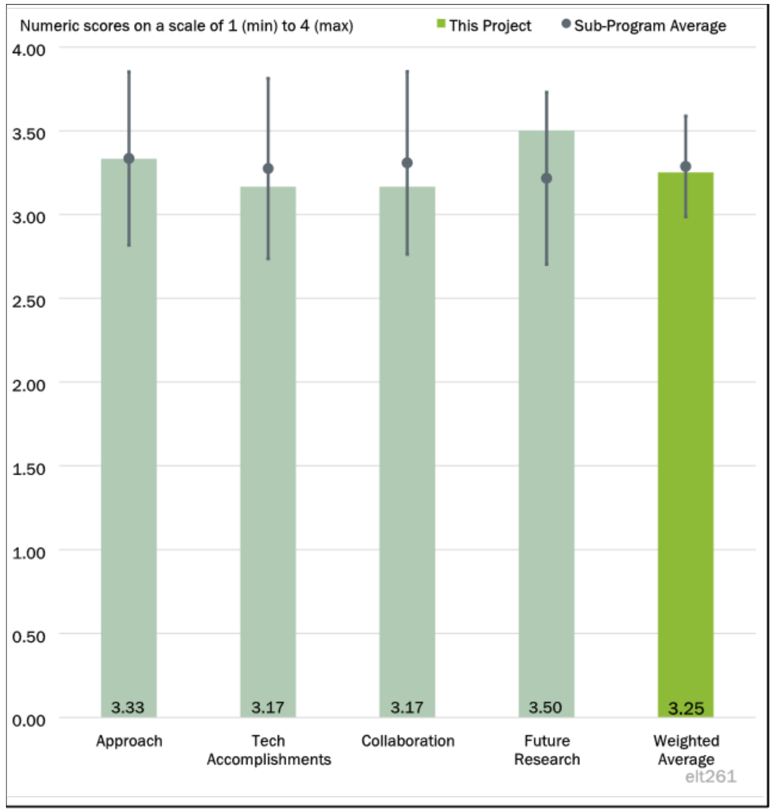

Figure 4-27 - Presentation Number: elt261 Presentation Title: High-Efficiency Powertrain for Heavy-Duty Trucks using Silicon Carbide Inverter Principal Investigator: Steve Peelman, Ricardo

Presenter

Steve Peelman, Ricardo

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that the project approach is excellent.

Reviewer 2

This reviewer said that developing an A-sample of a SiC inverter to assess technology feasibility followed by fabrication of eighty units of B-sample of SiC inverter for performance evaluations including conformation of inverter efficiency of 98.5% is a logical and appropriate approach taken by the project team. The B-sample allowed for creation of the SiC inverter ecosystem and all necessary know-how for Ricardo to proceed.

The reviewer believed that the inverter efficiency needs to be re-measured at elevated inverter coolant temperatures and ambient temperatures around the inverter because, at 25°C ambient and 25°C coolant, 98.5% efficiency may not mean much for TransPower’s real world application of the SiC inverter.

Reviewer 3

This reviewer said that the overall approach seems reasonable for achieving the stated objectives—specifically, going through first an A and then a B development cycle to produce an inverter satisfying the stated efficiency, power and power density targets, and subsequently demonstrating the developed inverter through in-use operation in a vehicle. Likewise, the approach for the current budget period seems appropriate i.e., completing development and testing on the B-sample inverter and preparing for vehicle installation and testing. The reviewer would have liked to get a little more information on the rationale/source for the stated goals, for instance, whether these were defined by the funding call that awarded this specific project. In the Electrification Annual Progress Report, some of the ultimate goals called out for the Electric Drive Technologies Lab Consortium appear to be more aggressive than the goals called out for this project, so it would be good to better understand how those relate to each other along with to the current state of the art at the outset of the project. The reviewer also would have preferred for the milestone table to include the dates of the listed interim milestones.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer said that very good progress is being made.

Reviewer 2

This reviewer said that the presentation highlighted quite a few accomplishments and challenges that had to be overcome to achieve them. Key accomplishments included successful B-sample inverter development and operation at or above the target power level, and preparation of the Peterbilt truck for in-vehicle testing in the final year of the project. The presenter also provided a verbal update that, since the time when the slides were put together, the bench testing has now slightly exceeded the target 98.5% operating efficiency goal with power output exceeding 250 kW. The presenter also noted that the results are currently showing a roughly 44 kW/L energy density, but that the team has some modifications planned to hopefully exceed the 50 kW/L design target. The reviewer would like to see a consolidated table listing the full set of design targets and the project status against achieving each. As cost is certainly an important target, the reviewer would like to see this included as well, or at least to have an indication that this is something being discussed and reviewed with DOE to confirm commercial viability.

Reviewer 3

This reviewer said that the project tasks and milestone are tracking, including fabrication of B-sample of SiC inverter followed by testing with a power supply as a DC source. Hardware and software requirements have been developed for the SiC inverter. Power module thermal simulation has been completed. Current sensor performance has been evaluated for command (torque) tracking. B-sample CFD simulation for thermal performance has been completed. Functional samples of 250 kW SiC inverter has been fabricated and pictures showing internal details are included in the project report. SiC power devices are double pulsed and improved DC bus contributed (50%) to the 23% improvements in performance of SiC switches.

Vehicle level powertrain development work is in progress, which task is led by Meritor (TransPower Inc.).

This reviewer has a significant concern, which is that when the inverter is powered by the battery-pack, efficiency may not hold at 98.5%, particularly when the coolant temperature is nearly that of the coolant flowing through battery-pack if the batteries are liquid cooled and experience temperatures far above 25°C.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer found that there are some good collaborations.

Reviewer 2

This reviewer found, from the presentation, that it seems that the Ricardo, Meritor, and NC State sub-teams work effectively together, and that each adds value to the project in complementary ways. There is no direct national lab collaboration on the project, but, hopefully, the project team is keeping abreast of relevant advancements by the labs.

Reviewer 3

This reviewer found that good collaboration exists between Ricardo and Meritor. NC State University is effectively supporting inverter development work and testing of the inverter with power inductors used for experimental simulation of three-phase R-L load.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer noted that the immediate next steps for the project are to complete the suite of inverter tests along with inverter integration into the two Class 8 electrified trucks. The presenter indicated that dynamometer testing had gotten pushed back from the original schedule of June but that it is now planned for that to happen this July. The final planned phase for the project will be to complete high mileage accumulation during demonstration and to capture, analyze, and report on the collected data.

Reviewer 2

This reviewer said that the proposed future research is clearly defined and good.

Reviewer 3

This reviewer said that future research is outlined in the project report including dynomometer scale characterization, which could be a scenario close to a real-world application of the 250kW SiC inverter.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the project is relevant to the Electrification Program goals to increase the efficiency and power density of inverters for electrified heavy-duty truck applications.

Reviewer 2

This reviewer said that the project is relevant and supports the VTO objectives.

Reviewer 3

This reviewer said that a high efficiency and high power SiC inverter is needed for US truck fleets for commercial operations of greater than 250 miles/day. This project advances this objective of DOE-VTO and, hence, research executed and technology development work underway in this project are quite relevant to the DOE-VTO roadmap and objectives.

*Question 6: **Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?***

Reviewer 1

This reviewer said that the resources appear to be adequate for the project, with DOE providing roughly 62% of the funding, and cost share from the project team covering the remainder.

Reviewer 2

This reviewer said that the resources appear to be sufficient.

Reviewer 3

This reviewer said that the project team has the necessary resources and technical expertise and know-how to successfully complete this project.

Presentation Number: elt262
Presentation Title: Long-Range, Heavy-Duty Battery-Electric Vehicle with Megawatt Wireless Charging
Principal Investigator: Stan DeLizo, Kenworth

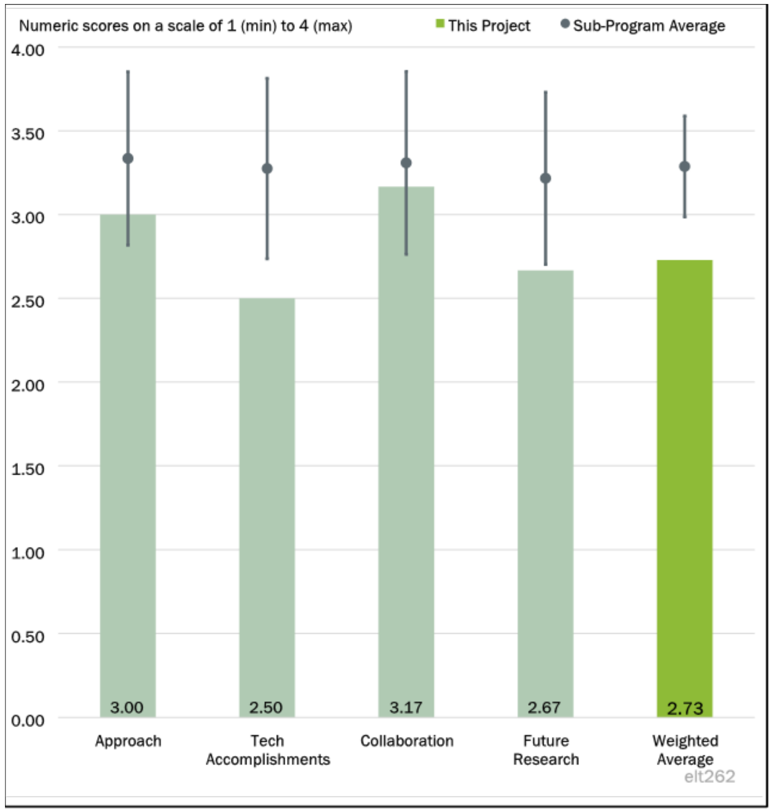

Figure 4-28 - Presentation Number: elt262 Presentation Title: Long-Range, Heavy-Duty Battery-Electric Vehicle with Megawatt Wireless Charging Principal Investigator: Stan DeLizo, Kenworth

Presenter

Stan DeLizo, Kenworth

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that the project is ambitious and seems to have run into some execution difficulties. The goal of developing a MW charging system is challenging and worthwhile, but the reviewer found it surprising that the technical work for the wireless charger is led by Utah State University with WAVE supporting, rather than being a more collaborative effort.

Reviewer 2

This reviewer believed that the work plan was designed sensibly, with modeling preceding actual builds. With hindsight, orders for materials probably could have been placed sooner, but it's hard to predict pandemic-related supply-chain problems. The reviewer would have preferred for the presentation to have included more descriptive illustrations of how and where the charging system was to be constructed and attached. The reviewer wondered what would happen if a small dog wandered into the facility and would also like to see the charger demonstrated in torrential rain. The system is going to need extensive testing, when they finally put it together.

Reviewer 3

This reviewer said that the project is designed to mitigate potential issues but the risks are not necessarily due to the project design. Many issues are due to supply chain and pandemic issues and are likely to persist in the short and medium term. Given the risk and that go/no-go decisions are already delayed, the reviewer believes that the project will continue to fall behind schedule.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

This reviewer said that the project has suffered some setbacks due to component shortages and appears to have a plan in place to recover some lost time and address delays. Progress on the truck and battery development is good. The team should clarify the "expanded wireless pad testing from 125kW to 850kW" accomplishment on Slide 7, whether 850kW testing has commenced or does the slide mean only that an 850kW system will be build to test. The reviewer said that there was not a clear answer to this question during the review.

Reviewer 2

This reviewer believes that the team really needs to get an extension because it is behind on many milestones. Basically, it looks like the team completed all the modeling but ran into major delays due to supply-chain issues with parts for the actual build. The reviewer believes that modifications made to enable moving forward obviously were not enough to conquer the obstacles in their path.

Reviewer 3

This reviewer's big question with this project is competing technology. By the time this project, delayed as it is, achieves any project milestones, competing fuel cell technology may have evolved. The reviewer's other concern is the impact to the electric grid, in that any upgrades on the utility side may mitigate any speed to market advantage battery electric vehicles may have. Rather than continuing to extend project deadlines, the reviewer suggests that a better approach might be completely re-evaluate project timelines and then compare those timelines with fuel cell demonstration projects. Because the dates have been pushed out already, and given the pandemic and supply chain issues, any new timeline should take those factors into account. The reviewer questions whether it is still possible for the project to achieve its stated objectives before funding expires.

Question 3: Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1

This reviewer said that the project has all of the key players onboard, from modeling and designing to building and testing, and to actual on-road application. To some extent, they work in series rather than in parallel, so they are serially collaborating. It is unclear to this reviewer how much interaction happened between the university partner and the actual truck operators.

Reviewer 2

This reviewer believes that the necessary partners to make the project successful are in place and collaborating. The reviewer finds it is somewhat surprising that WAVE is supporting rather than co-leading the wireless charger development.

Reviewer 3

This reviewer believes that there are many touchpoints, both virtual and in person, so collaboration is happening and this is not the project's weak point.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the future work to get back on track and complete the project contains appropriate steps.

Reviewer 2

This reviewer said that the team's job now is pretty clear: to get the system built and running. Test results will be crucial. The reviewer would then like to see the team do a TEA to estimate the cost of a commercial system.

Reviewer 3

This reviewer reported not being confident that the project will achieve its objectives, given current industry challenges, at least in the funding timeframe.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the project is a technology demonstration for the kind of charging that will be needed to make electrification practical in the medium and heavy duty truck sector.

Reviewer 2

This reviewer said that enabling of fast charging for heavy vehicles would enable electrification without huge expenditures for huge, heavy batteries. That would remove a big barrier to electrification of long-haul trucking.

Reviewer 3

This reviewer said that the project supports electrification.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer believed that the resources are sufficient and would not suggest adding additional resources, given there are industry challenges that added resources to the project won't overcome.

Reviewer 2

This reviewer believes that this question is always impossible to answer meaningfully without any detailed accounting for the budget. But resources seem reasonable.

Reviewer 3

This reviewer believes that the project needs more resources to accelerate the project to completion.

Presentation Number: elt263
Presentation Title: Low-Cost Rare-Earth-Free Electric Drivetrain Enabled by Novel Permanent Magnets, Inverter, Integrated Design and Advanced Thermal Management
Principal Investigator: Ayman El-Refaie, Marquette

Presenter

Ayman El-Refaie, Marquette

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

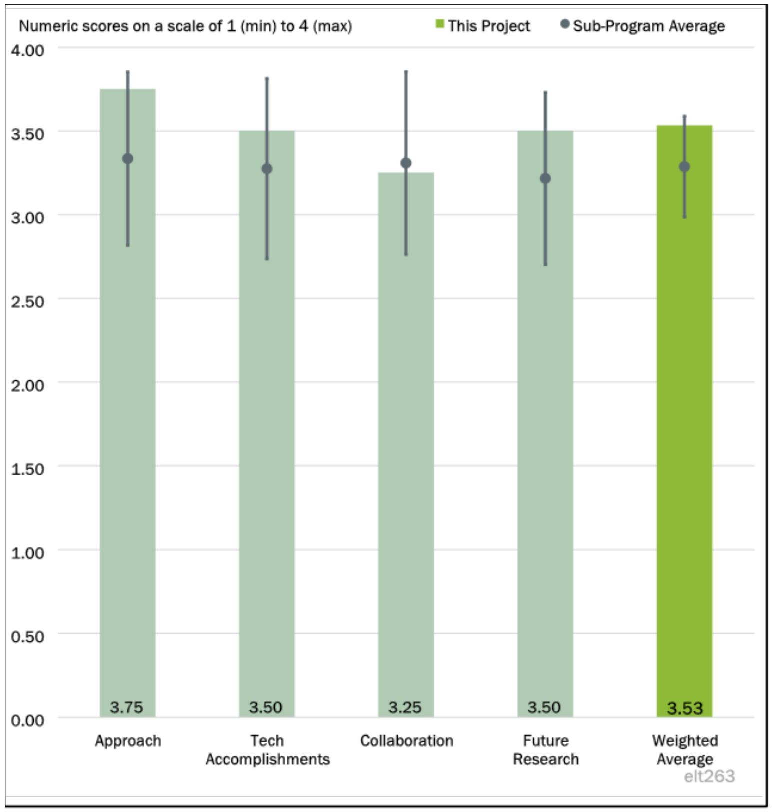

Figure 4-29 - Presentation Number: elt263 Presentation Title: Low-Cost Rare-Earth-Free Electric Drivetrain Enabled by Novel Permanent Magnets, Inverter, Integrated Design and Advanced Thermal Management Principal Investigator: Ayman El-Refaie, Marquette

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

This reviewer said that, so far, the approach is well planned and detailed

Reviewer 2

This reviewer believed that an appropriate development process is being used and that a thorough analysis has been done to optimize the design. Testing is comprehensive using a production vehicle traction system as a baseline.

Reviewer 3

This reviewer believed that the team may want to consider a waterfall type chart to collect the accomplishments and highlight the manner that you targets are achieved.

Reviewer 4

This reviewer noted that baseline data (Chevy Bolt) and proposed data for a rare-earth mineral-free electric motor are outlined in the project report. Concept and tradeoffs study will be carried out and optimized design of the rare-earth mineral-free electric motor will be down-selected. Budget period 1 tasks are dedicated for concept development, BP2 tasks are for design and optimization and sub-component and component testing and BP3 tasks are for system integration and system level verification of the rare-earth mineral-free electric motor. This approach is quite logical and systematic. Niron's expertise is being used for manufacturing of an iron-nitride permanent magnet. Inverter development will be carried out using 900V discrete MOSFETs populate down heavy-pour cooper printed circuit board (PCB), mostly using surface mount components including current sensors. Also, the project aims to reduce rare-earth-free magnets to maximum extent. Overall, this reviewer rated the project approach as excellent.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer believed that this is a well thought out project.

Reviewer 2

This reviewer said that the discussion and written presentation were both good.

Reviewer 3

This reviewer pointed out that preliminary optimization results for the rare-earth mineral-free motor are included in the project report. Layered magnets with V-shape are indicated in the project report. Limited amounts of coated nanoparticles of iron nitride magnets are produced. The possibility of uniform coating on iron nitride nanoparticles was verified. Tooling for magnet material manufacturing was designed and fabricated. The team measured and understood hysterias loops on deagglomerated nanoparticles dispersed and magnetically aligned in epoxy environment. Two concepts of traction inverter were illustrated in the project report and were described very well during the AMR presentation. Effects of parasitic inductance in the packaging of the gate driver with power stage were understood and layout with minimal inductance is illustrated in the project report.

This reviewer had a few concerns including SiC MOSFETs embedded in PCB, as PCB technology with high-voltage parts embedded may not be mature enough by completion of this project. Therefore, the project PI could have industry impacting contributions by focusing efforts on more feasible technology, which is to use discrete MOSFETs populated on a heavy-copper-pour PCB.

This reviewer has offered some suggestions. The discrete MOSFETs have a common footprint for 900V to 1200V blocking parts. Therefore, for technology with higher levels of confidence, 1200V SiC MOSFETs should be preferred over 900V SiC MOSFETs to achieve 300,000 miles reliability and 15 years life. Use of ceramic capacitors must be considered carefully, as capacitance value of these capacitors suffer from voltage and temperature related biases.

Reviewer 4

This reviewer perceived that the project is still in the planning stage

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer found that this is a very experienced team with all the essential elements to be successful. Based on the progress, it is clear that collaboration is continuous.

Reviewer 2

This reviewer said that, though only 10% of the project is completed, universities (Marquette and Virginia Tech), supporting industries (Niron Magnetics and GM) and NREL are collaborating very well in execution of this project.

Reviewer 3

This reviewer found good planning between the collaborators

Reviewer 4

This reviewer suggested that the team may want to list the work or deliverables expected from each partner.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer found that there is a clear plan being executed.

Reviewer 2

This reviewer said that the future work is planned well and should help address many of the challenges.

Reviewer 3

The reviewer had no comments.

Reviewer 4

This reviewer said that the future work was described very well.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer believes that the project is critical to achieving a low cost, high power density application.

Reviewer 2

This reviewer found the project to be highly relevant to achieving the VTO electric powertrain goals.

Reviewer 3

This reviewer said that a rare-earth mineral-free electric machine will advance the DOE-VTO objective of strengthening the supply chain of electric motors and make these motors free from magnets imported from foreign soil, mainly China.

Reviewer 4

This reviewer said that this work supports achieving VTO traction drive targets.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the project is on track.

Reviewer 2

The reviewer had no comments.

Reviewer 3

This reviewer said that the project team has all necessary resources and technical know-how and expertise.

Reviewer 4

This reviewer said that the team has the resources needed for a successful outcome.

Presentation Number: elt264
Presentation Title: Demonstration of Utility Managed Smart Charging For Multiple Benefit Streams
Principal Investigator: Joe Picarelli, Exelon/Pepco Holdings Inc.

Presenter

Stephanie Leach, Exelon/Pepco Holdings Inc.

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

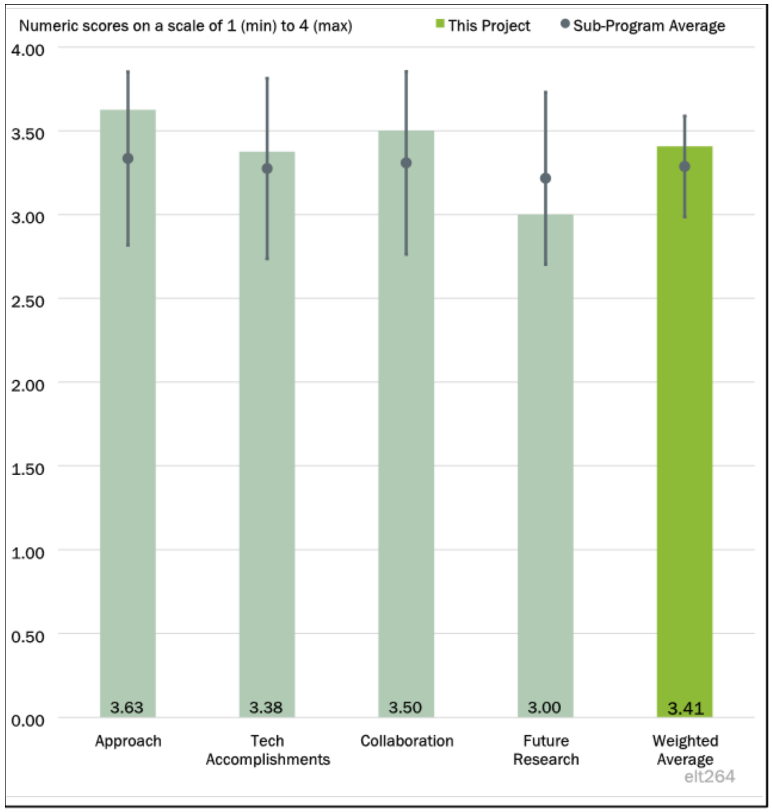

Figure 4-30 - Presentation Number: elt264 Presentation Title: Demonstration of Utility Managed Smart Charging For Multiple Benefit Streams Principal Investigator: Joe Picarelli, Exelon/Pepco Holdings Inc.

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

This reviewer said that the objectives and expected outcomes/milestones are clearly identified (Slide 6 of the presentation) and tie closely with the overall project objective of demonstrating large-scale smart charging.

Reviewer 2

This reviewer found that the approach was expertly planned and sought to answer the key questions related to EV charging. Including industry research and customer feedback is a huge advantage to project competitiveness among many others in the space. The principal investigator seems to have a good handle on such a massive project and is coordinating with many different aspects of the EV industry, which is important to gaining buy-in.

Reviewer 3

This reviewer defined the objectives of the project as: to research, develop, and conduct a wide-scale demonstration of a utility smart charge management (SCM) system; to develop optimal managed charging structures for grid value; to evaluate the impact of EV charging on local distribution utility operations; and to evaluate the utilities' ability to control EV charging load based on grid conditions. The reviewer identified as strengths the project appears to cover most major salient elements and demonstrates a logical progression from establishment of cybersecurity assessment/recommendations; identification of EVSE and telematics to receive

DR events; design of SCM demonstration; completion of ATEAM simulation software; development and conducting of a custom engagement program; and completion of model results to provide grid impact analysis.

He reviewer identified as weaknesses the project's go/no-go milestones could be stronger. No technical go/no-go milestones have been established and the third go/go-go milestone (December 2023) is the same as the December 2022 go/no-go milestone.

Reviewer 4

This reviewer felt that the project addresses the technical barriers and the project appears well designed and reasonably planned.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

This reviewer said that the team is on track towards completing the project plan. Numerous milestones and objectives have been achieved successfully, including responses to prior year reviewers' comments. A key example is looking at cybersecurity vulnerability and defense strategies. It is also critical that the benefit and cost analysis be performed as planned (see Slide 9). Regarding this analysis, non-financial costs should be included as well, particularly regulatory barriers to implementation, i.e., what regulatory rules will need to be adopted to enable wide-scale smart charging. While the focus is the technical implementation and program demonstration, any regulatory barriers—such as lack of required rules for utility participation in smart charging—are as important as technical barriers in achieving successful smart charge deployment.

Reviewer 2

This reviewer said that the project appears to have made significant technical progress in the last year on all fronts with regards to cybersecurity, demand response using EVSE platforms, design of the customer SCM and launch of marketing recruitment planning, and the ATEAM grid simulation software tool.

Especially promising, according to the reviewer, is the cybersecurity progress, specifically the efforts to obtain broad feedback early on from stakeholders (including EVSE and telematics providers) on attack graphs, threat models, and identified vulnerabilities. Additionally, coordination with the National Institute of Standards and Technology best practices/guidelines and the MITRE ATT&CK framework is encouraging.

Furthermore, with regards to the customer SCM program, efforts here to specifically target and tailor smart charge measures to each customer segment is well received.

Reviewer 3

This reviewer found that many milestones have been achieved and the project is on track. The team did a great job on addressing cyber concerns and including customer feedback. The reviewer believes that these issues are front and center as managed charging and grid impacts are discussed.

Reviewer 4

This reviewer believed that the technical progress has been good except for the design for the SCM programs. The explanation for how the unique incentives were developed is lacking.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer affirmed that collaboration is key and found the project team to be collaborating well.

Reviewer 2

This reviewer said that the team is working well together and accomplishing complex tasks on both the technical and program side, including the integration with OpenADR and securing program approval from the Maryland Public Service Commission.

Reviewer 3

This reviewer said that the effort has a strong, balanced team that appears to fulfill all requirements to achieve the project objectives. This includes Baltimore Gas and Electric (BGE)/Pepco for project lead, integration, and customer demonstration program; Argonne National Laboratory for grid impact analysis/modelling, cost benefit analysis, and cyber assessment; Shell Recharge Solutions to serve as a hardware and network provider; WeaveGrid as a telematics software solution provider and for evaluation of the ability to control EV charging load; and the Smart Electric Power Alliance to provide SCM program market research. There do not appear to be any overt gaps within the project team, nor lack of availability of resources and equipment to appropriately conduct project activities.

Reviewer 4

This reviewer said that there is a good representation of different types of partners.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the project has done a good job of comprehensively identifying remaining programmatic, business, and technical barriers. The budget period 4 proposed research is a logical progression from the previous year, and can be assumed to address the remaining barriers. Additional detail under each element of the expected outcomes/milestones of budget period 4 would have been beneficial to further clarify expectations.

Reviewer 2

This reviewer said that the team has noted two remaining barriers and challenges but its proposed future research does not include a plan to address them. The two barriers are, “Not all EVSE hardware providers can perform DR events for public program” and “Inconsistent firmware on EVSE used across fleet and public programs.” (Slide 11) The solution involves interoperability and standards; the team should identify which existing standards are available to solve the problems.

Reviewer 3

This reviewer felt that the project needs to clearly identify incentives and what is the appropriate level to get customers to participate. This is important especially to get participation in SCM at scale.

Reviewer 4

This reviewer saw the reliability of EVSE equipment and how downtime may affect managed EV charging pilots as a challenge forthcoming. The reviewer suggested that, with firmware being inconsistent and physical hardware being possibly unreliable, one way to work around this would be a service level agreement that seeks a standard amount of uptime and coordinates across all vendors (Shell Recharge, Weave Grid, etc.).

Another issue could be a possible large T and/or D impact is found. The reviewer questioned how that would impact BGE operations at scale, especially in power delivery, workforce planning, Etc. The reviewer believed that downstream impacts do not have to be solved for in this project but they should be identified to spark industry discussion.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the project aligns with subprogram objectives.

Reviewer 2

This reviewer pointed out that the project targets VTO's Smart Charge Management objectives. Specifically, it tests a potentially (depending on the cost-benefit analysis and consumer adoption) viable smart charge management strategy, as well as specific tools (e.g., ATEAM) relevant to creating, implementing, and operating smart charge management programs at scale. The reviewer raised the question as to what interoperability standards are needed to scale such programs and achieve the best economics.

Reviewer 3

This reviewer found that this project is highly relevant. If successful, the project will facilitate earlier, more widespread and resilient EV-grid integration, which will enable EVs at scale. Specifically, this will be achieved through reduced EV charging impacts on utility distribution/transmission systems, lowering of capital investment requirements, and early identification of cybersecurity risks and vulnerabilities.

Reviewer 4

This reviewer found that the program supports electrification.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the resources are sufficient and the project should meet the milestones on time.

Reviewer 2

This reviewer said that, based on experience with comparable pilot programs such as California's Statewide Pricing Pilot and more recent Residential TOU Program Pilot, the budget appears adequate.

Reviewer 3

This reviewer said that the resources identified are sufficient for the identified scope and duration of this project.

Reviewer 4

This reviewer said that the project has sufficient resources.

Presentation Number: elt265
Presentation Title: A Secure and Resilient Interoperable Smart Charging Management (SCM) Control System Architecture for Electric Vehicle's-At-Scale
Principal Investigator: Duncan Woodbury, Dream Team LLC

Presenter

Duncan Woodbury, Dream Team LLC

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

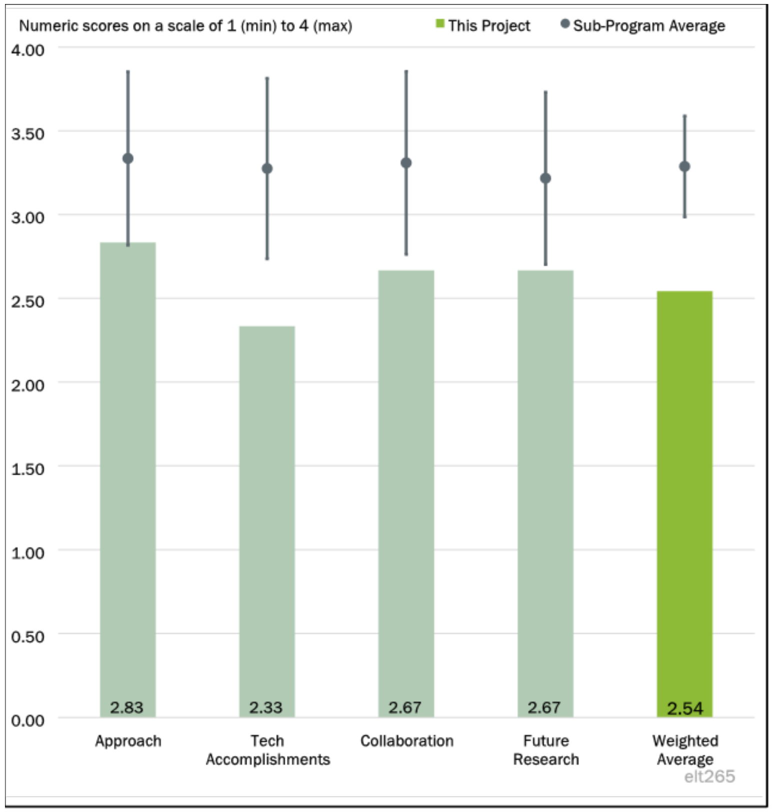

Figure 4-31 - Presentation Number: elt265 Presentation Title: A Secure and Resilient Interoperable Smart Charging Management (SCM) Control System Architecture for Electric Vehicle's-At-Scale Principal Investigator: Duncan Woodbury, Dream Team LLC

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that the approach seems generally aligned with addressing the identified technical challenges related to interoperability and cyber security concerns from heterogeneous electrified vehicles, charging stations, and distributed energy resources connecting with each other and the utility grid.

Reviewer 2

This reviewer said that the approach seems good. The project relevance could be described in a more effective graphical format.

Reviewer 3

This reviewer said that the approach appears to focus on both security and interoperability but does not list existing standards for a comparison with this project's objectives of creating a new standard. According to the reviewer, IEC61850-90-8 is being used but this is obsolete and IEC 61850-7-420 should be used instead.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer found the presentation difficult to follow and, thus, the impact of the accomplishment was unclear.

Reviewer 2

This reviewer said that the presentation reported accomplishments related to system architecture development (though it needed to clarify completion dates for this in 2021 rather than 2022), data model specification, and laboratory testing/demonstration. It would, however, be beneficial for the project to more closely follow best practices to define "SMART" milestones—particularly the specific and measurable elements of the mnemonic, along with being achievable, relevant and time bound.

Reviewer 3

This reviewer said that significant variations to interoperability vary with architectural differences for direct current fast-charging (DCFC) versus DWPT. This is not addressed. The focus seems to be on multiple power levels of DCFC where that is not a factor for security or interoperability.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

Tis reviewer said that the project includes a good diverse team of listed contributors, spanning utility stakeholders and national laboratory and university collaborators, along with industry partners and multiple test and demonstration locations.

Reviewer 2

This reviewer said that the partners are diverse but more needs to be identified regarding their resources to provide results for the tasks.

Reviewer 3

This reviewer said that the collaborative aspects of the project were not clear.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer found that the described future work seems on track and appropriate—noting that the listed activities will span the upcoming budget period through the remainder of FY22 and FY23, but that there will be further activities happening in the final portion of the project through the end of 2024.The reviewer believed, however, that it would be good to strengthen the specificity and quantifiable metrics associated with the future milestones wherever possible.

Reviewer 2

This reviewer said that the proposed work seems consistent with the plan, but the broad goals of the project are still somewhat obscure.

Reviewer 3

This reviewer suggested that clarity needs to be included as to the approach for vehicle grid integration versus V2G. Is the approach to only control the EVSE or insure security and interoperability to the EV?

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer felt that a stronger, more concise, and graphical explanation of the targets and accomplishments would significantly enhance communication of the relevance of this project.

Reviewer 2

This reviewer said that the project is relevant to the electric vehicle, grid, and charging infrastructure interoperability and cyber security considerations of concern to the VTO Electrification Program.

Reviewer 3

This reviewer affirmed that this an important project as electrification increases and the grid also changes to include more clean energy options. Matching these needs will continue to be a challenge as these changes are evaluated.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the resources seem sufficient.

Reviewer 2

This reviewer said that the resources appear to be adequate for the project, with DOE providing a little over 2/3 of the funding, and cost share from the project team covering the remainder.

Reviewer 3

This reviewer believed that assignments need to be identified to point out the strengths of them and how they will best fit in obtaining expected results. Each stakeholder support and expected contribution needs to be identified to provide positive results to the project.

Presentation Number: elt266
Presentation Title: Next Generation Profiles: High Power Charging Characterization
Principal Investigator: Dan Dobrzynski, Argonne National Laboratory

Presenter

Dan Dobrzynski, ANL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

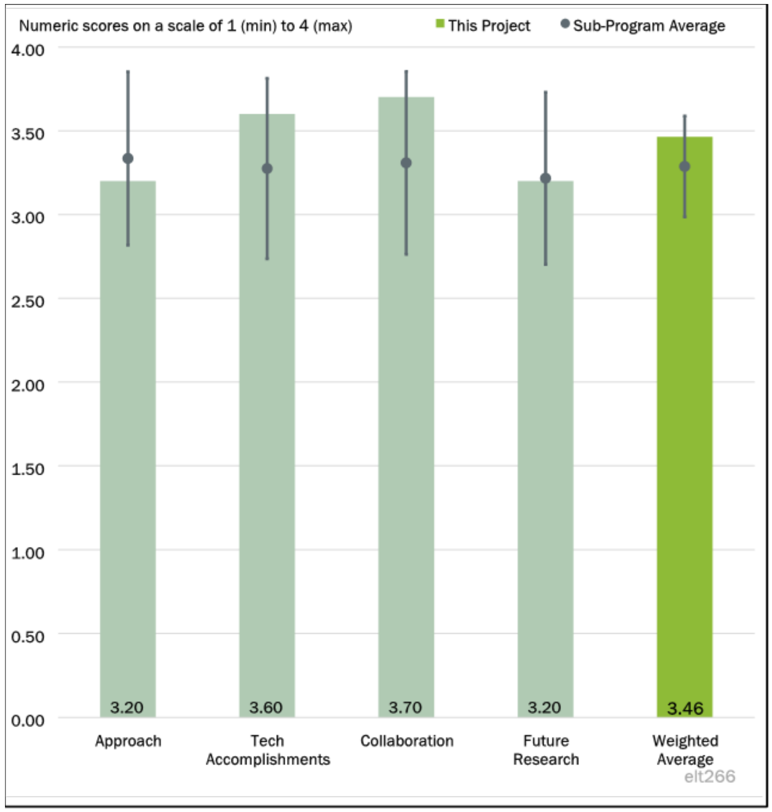

Figure 4-32 - Presentation Number: elt266 Presentation Title: Next Generation Profiles: High Power Charging Characterization Principal Investigator: Dan Dobrzynski, Argonne National Laboratory

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that the Involvement of partners, standards groups, and the Grid Integration Technical Team in the development of procedures helps assure that the data collected will be useful for planning grid and charge infrastructure development.

Reviewer 2

This reviewer found that the team has a comprehensive plan for obtaining data. One concern the reviewer raised is the ability to correlate lab testing with actual field conditions, noting that field data is noisy and difficult to obtain, but lab data may or may not reflect actual usage patterns. The plan does have some accommodation of those concerns, though.

Reviewer 3

This reviewer believed that there is an implied assumption that the measured HPC profiles are relatively static and will not change with time. It appears that most vehicle OEMs limit the number of times that fast charging can be used (to prevent battery life degradation). It is also possible that as more fast charging cycles are completed, the charging profile may be changed to ensure longer battery life. Also, as more vehicles start offering HPC, and the take rate goes up, the impact on the grid will become clearer, and may lead to further modification of the HPC profiles.

The reviewer also questioned whether XFC and HPC defined in terms of power level or C-rate. Defining it in terms of power level makes sense because the primary goal is to study the grid impact, and not the impact on the battery (though the reviewer felt that, as long as the money is being spent, it makes sense to study the impact on the battery as well). However, as one of the reviewers pointed out in the previous year, the definitions as used by the PI may be confusing, since apparently XFC is generally defined in terms of C-rate.

Reviewer 4

This reviewer said that achieving this project's objectives regarding identification and characterization of HPC profiles requires broad participation by providers of EVs and EVSEs, a difficult task that has been largely successfully achieved. The EVSE characterization utilizes an EV emulator load; it is unlikely that the emulator will reflect the diversity of charging behavior of actual EVs of different types and models. It would be more valuable to characterize EVSE's by using actual EV loads, even though this is more difficult. Regarding the timeline, the Year 2 Milestones do not appear likely to be achieved on schedule, though it is possible that the delays will not affect overall project completion.

Reviewer 5

This reviewer believed that the approach to the work is very good. This is creating a set of power profiles for potential future grid evaluations. The reviewer did, however, have some concerns about how the creation of these data will align with a full fleet of vehicles, the wide spread of potential vehicle use cases, and potential future smart charging or pre-charging preparations where drivers know they are going to charge and the vehicle preps the battery for charging prior to reaching the charge station.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer thought that the team has done an excellent job of getting engagement from OEMs and fleet managers, particularly considering pandemic-related restrictions. It appears to be well-positioned for the next phase of the project.

Reviewer 2

According to this reviewer, the data acquisition systems look good. The reviewer expressed hope to see a distribution of charging profiles that estimate not only a current nominal, but also a future nominal that includes forecasting improvements in hardware, system integration, and controls.

Reviewer 3

This reviewer said that, despite the COVID-19 related delays, significant progress has been made on the project.

Reviewer 4

This reviewer found that, overall, achieving the technical goals has been very successful, including the enrollment of partners, EVSE characterization, and fleet data collection. The Year 2 Milestones do not appear likely to be achieved on schedule, though it's possible the delays will not affect overall project completion.

Reviewer 5

This reviewer said that a significant amount of data has been collected in spite of some setbacks in asset availability and interest in the field. Development of post-collection analysis remains to be accomplished. This task is critical to bringing value to the data collected.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer found that the procedure reviews within the labs and coordination of data collection with vehicle manufacturers, EVSE suppliers, fleet operators and electric utilities was excellent.

Reviewer 2

This reviewer said that each team member has clearly-defined roles and appears to be interacting appropriately.

Reviewer 3

This reviewer said that the four lab partners have shown previous success working together on similar projects. The reviewer was hopeful that continued OEM involvement will continue to make the results valuable to all future users.

Reviewer 4

This reviewer found that the PI has done due diligence and reached out to various vehicle and EVSE OEMs and labs, though some partners appear to have pulled back.

Reviewer 5

This reviewer believed that, while the current team is working well together, the team does not include any EVSP participants. EVSPs, which lead the design and construction of charging depots, will be among the main customers of the outputs of this research. EVSPs will use this research to plan their depots, engineer their utility interconnections, and participate in grid service offerings. The data will be the main input to determining how to manage loads to minimize electricity costs for HPC sites, because demand charges are the largest determinant of those costs. Accordingly, addition of one or more leading EVSPs to the team as an advisor or participant is highly recommended.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the team has a good plan and is well-positioned for the next phase. However, this is a highly fluid technology space, with new vehicles and EVSE being released regularly. Flexibility is required to ensure broad impact, but the team is struggling some to turn letters of intent into contracts. This is a relatively minor concern, related not to the quality of the work but to its breadth.

Reviewer 2

This reviewer suggested that collaborative engagements should include one or more leading EVSPs as described in the response to Question 6. EVSE characterization should go beyond the emulator and include actual vehicles.

Reviewer 3

This reviewer noted that, as the PI has mentioned, there needs to more effort to engage other OEMs and partners.

Reviewer 4

This reviewer pointed out that the project mentions SAE, Electric Power Research Institute (EPRI), Energy Star for Utilities that participate. The reviewer would like to see more information from the electric utilities on how the data are valuable to them for grid forecasting and minimizing disruptions or for optimizing the current system to provide a robust charging experience to future EV users.

Reviewer 5

This reviewer said that analysis, results, and reporting is only one of four milestones for Year 3. This work is what brings value to all the effort to collect data. It should receive a much higher priority for future research.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the project is relevant to both ELT and Energy Efficient Mobility Systems.

Reviewer 2

This reviewer said that the project provides data that are central to future grid studies.

Reviewer 3

This reviewer found that the project matches the following goal: "HPC: Develop strategies and technologies for high power dynamic wireless charging and multi-port 1+ MW charging stations that enable vehicle charging through direct connection to medium voltage (≥ 12.47 kV) distribution." While the goal specifies 1+ MW charging, there are no vehicles available that can accept such charging levels. It has been reported (Electrek, October 12, 2021) that Tesla has deployed a 1 MW charger; the project should attempt to obtain/borrow a MW charger from Tesla or other source and include it in its EVSE characterization efforts.

Reviewer 4

This reviewer said that, while benchmarking/measuring currently available products isn't directly changing the future electrification needs, the data will be useable for forecasting and proposing changes to improve the overall EV adoption rate.

Reviewer 5

This reviewer said that the project provides a baseline of data that will gain relevance only once it is analyzed for specific use cases.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer noted that the project reaches out to many groups to collect data. While there have been some setbacks in gaining cooperation with the project, the reviewer believes that this does not appear to be from lack of resources trying. The amount and variety of data collected is impressive.

Reviewer 2

This reviewer expressed to having no concerns about the resource level. The team is doing well to trade data for equipment access.

Reviewer 3

This reviewer said that the presenter noted that, in line with previous reviewer comments, the project resources are sufficient.

Reviewer 4

This reviewer found that the list of participating labs, vehicles, and equipment appear sufficient to achieve the project goals listed to be complete in Oct 2023.

Reviewer 5

This reviewer opined that the resources are sufficient as of now, but if there are a large number of HPC capable vehicle models available for sale in the near future, the budget may need to be increased so that a good data set can be generated.

Presentation Number: elt274
Presentation Title: eMosaic: Electrification Mosaic Platform for Grid-Informed Smart Charging Management
Principal Investigator: Alex Brissette, ABB

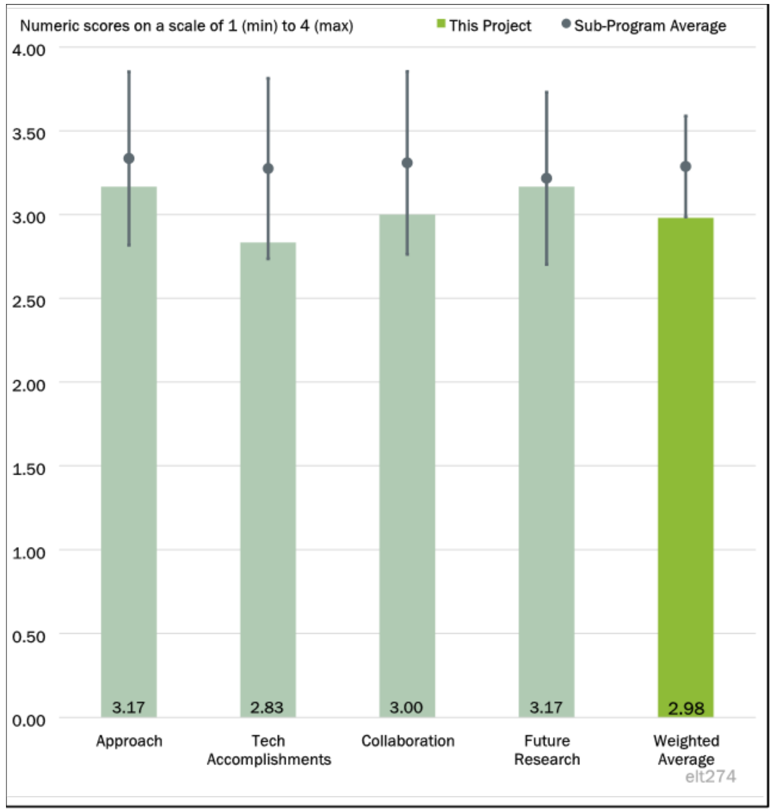

Figure 4-33 - Presentation Number: elt274 Presentation Title: eMosaic: Electrification Mosaic Platform for Grid-Informed Smart Charging Management Principal Investigator: Alex Brissette, ABB

Presenter

Alex Brissette, ABB

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer believes that the project appears to be well designed to address technical barriers and that the timeline is reasonable.

Reviewer 2

This reviewer said that the project's approach is well designed. The timelines have slipped a bit but that is expected given the ongoing pandemic and supply chain struggles.

Reviewer 3

This reviewer wanted to see the details on how the platform architecture on Slide 10 was selected including whether other architectures were considered, and if so how were they evaluated.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer found that the project seems generally on track.

Reviewer 2

This reviewer said that technical progress is well documented But information on how cybersecurity is being addressed is lacking wand will be important for integration with multiple platforms (utility, charging network operator, facility, and fleet management).

Reviewer 3

The reviewer had concerns that while the project may end up showing technically feasible results, the findings won't translate to implementation at scale.

The reviewer said that any project approach should consider the minimum NEVI standards being proposed by the joint DOE/U.S. Department of Transportation office. Plug and Charge (ISO 15118) is being considered as mandatory and there could be other developments such as cybersecurity modifications, after the comment period ends.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer found that the partners are well coordinated in tasks and contributions. The reviewer suggested that opportunities for stronger collaboration with fleet operators will occur moving forward and will be helpful with input to the project.

Reviewer 2

This reviewer thought that the project could be a candidate to be included in the EVs@ Scale Consortium as that project takes shape. Either way, the reviewer recommended more utility involvement, through EPRI or others. Good to see the ASPIRE Center is involved.

Reviewer 3

This reviewer would have liked to see specifics in the accomplishments section regarding which collaborators are responsible for the various outcomes that were reported out.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the proposed future work is in line with the project plan.

Reviewer 2

This reviewer said that the proposed work will achieve targets and address barriers.

Reviewer 3

This reviewer believed that the proposed future research has implications for the entire industry and will be valuable to all involved. The project plan acknowledges future research challenges and the need for additional stakeholder engagement, including the addition of a charge point operator. The reviewer believed that to be important because, according to the reviewer, if this project were developed without a network charge point operator involved, it would face much more scrutiny and acceptance challenges to commercialization.

Additionally, the ability for multiple utilities to follow project developments would be beneficial, especially if there are opportunities for pilots in other parts of the country.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the project is relevant to grid-scale adoption of smart charging.

Reviewer 2

This reviewer said that the project supports the VTO program objectives.

Reviewer 3

This reviewer said that the project supports electrification and analysis.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The resources seem sufficient.

Reviewer 2

Resources appear to be sufficient.

Reviewer 3

This reviewer said that the project is relatively on schedule given the industry-wide challenges. No additional resources specific to the project is needed but additional stakeholder input is recommended.

Presentation Number: elt277
Presentation Title: Electric Vehicle Integrated Safety, Intelligence, OperatioNs (eVision)
Principal Investigator: Madhu Chinthavali, Oak Ridge National Laboratory

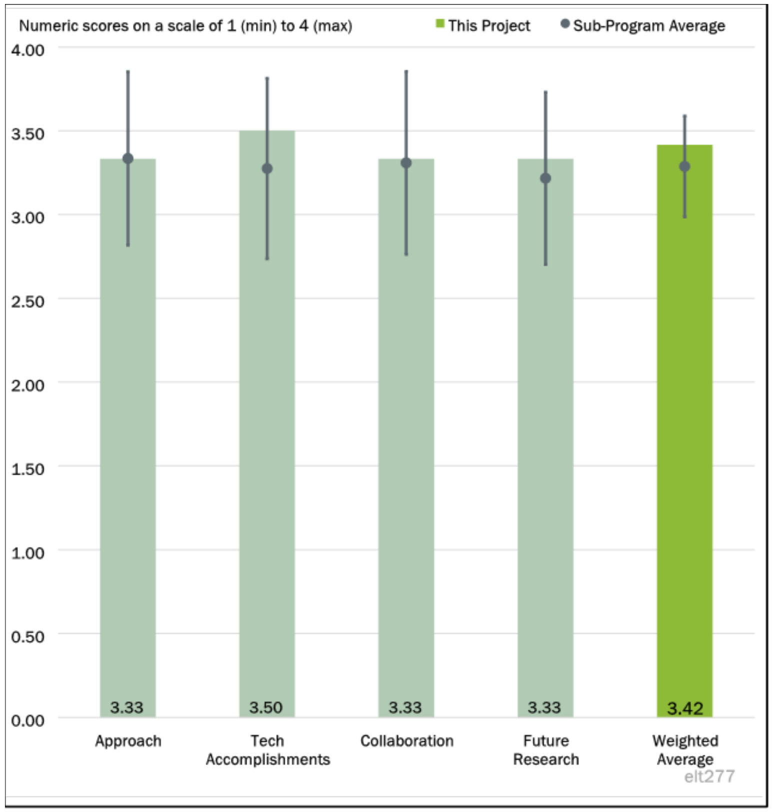

Figure 4-34 - Presentation Number: elt277 Presentation Title: Electric Vehicle Integrated Safety, Intelligence, OperatioNs (eVision) Principal Investigator: Madhu Chinthavali, Oak Ridge National Laboratory

Presenter

Madhu Chinthavali, ORNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that the technical barriers are addressed, the project is well designed, and the timeline is reasonable.

Reviewer 2

This reviewer believed that maintaining charging with minimal human interaction to recover from charge faults will help with the vehicle utility and overall adoption. Regarding the charging bank system designs, the reviewer asked whether there will be an optimization of the size of the ESS regulating the PCC and microgrid voltages. This component appears to have a large expense in the overall system, according to the reviewer so that using the throttling controls to minimize that ESS size will help reduce cost and improve adoption.

Reviewer 3

This reviewer said that the approach for the project is extremely complex and includes nine subtask areas. According to the reviewer this makes it somewhat difficult to follow, though, the reviewer recognizes that the project is trying to address multiple complex issues. Overall, the reviewer believes that it is really important that the project is looking to address charger outages, which has become a bit of an issue for the market. The project is focused specifically on three primary charger outage causes. This is an area where utility perspective may have been useful, according to the reviewer..

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

This reviewer said that the project made a good evaluation of charger architecture, controls and grid faults. The integration work was well done.

Reviewer 2

This reviewer said that ORNL has been able to characterize in detail several fault cases as well as related operating strategies for the use cases, for chargers both with and without storage. Idaho National Laboratory has been emulating failure modes in the lab to figure out how to set up hardware operation to address the various cases. Meanwhile, Pacific Northwest National Laboratory has worked to evaluate system control responses and focused on Charging Architecture Development Station Optimization and Control. Overall, the team has investigated a large number of use cases and responses in detail. While the complexity of the project approach/design makes it a bit tough to have a clear feel for the overall technical accomplishments and how they fit together, the team does appear to have accomplished a great deal. The real test will be to see how the team ties it all together.

Reviewer 3

This reviewer said that maintaining charging with minimal human interaction to recover from charge faults will help with the vehicle utility and overall adoption. The testing of the system and demonstrating the throttling of charge rate fast enough to prevent trips is good proof that the system is functioning as intended.

Question 3: Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1

This reviewer found that the five partners have produced good data so far. Nothing in the material indicates any of the partners are falling short.

Reviewer 2

This reviewer said that, overall, the project has a good team between national labs and ABB. Since grid faults are a major component, the project team should get feedback from a utility.

Reviewer 3

This reviewer noted that the project includes three labs, a charger manufacturer, and a university, suggesting that it would have been good to include a utility to provide an additional perspective related to the grid. The team has worked hard to ensure that the labs are collaborating on tasks. The same team is also leveraging three other DOE VTO projects.

Question 4: Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1

The project team identified several specific future challenges and barriers to address, based upon what they have accomplished to date and what they still want to achieve. They have laid out the remaining activities for FY2022 and FY2023.

Reviewer 2

This reviewer said that the project should explore testing beyond hardware in the loop and include field tests.

Reviewer 3

This reviewer said that the project does demonstrate many use cases. The future proposed research lists "Creating more use cases for the anomaly detection using test data from the chargers" but does not specify what methods or feedback from utilities and charger OEMs will be used to demonstrate that the droop and fault detection is comprehensive and not specific.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the project aligns with electrification objectives.

Reviewer 2

This reviewer said that the project is focused on charging station resiliency (including impacts on the grid and cyber security), charger approaches for MD/HD EVs, and charging station architecture for extreme fast chargers and that these are all of great relevance to the DOE program.

Reviewer 3

This reviewer said that EV charging robustness to many use cases and potential systems faults will improve vehicle utility and the adoption rate of technology.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the project resources are sufficient and it is expected that the milestones will be met in a timely fashion.

Reviewer 2

This reviewer said that there was no indication of concerns on resources.

Reviewer 3

This reviewer said that the material does not list a resource shortfall to completing in 2023. The partners appear to be on track.

Presentation Number: elt278
Presentation Title: Electric Vehicles (EVs) at Scale Laboratory Consortium
Principal Investigator: Andrew Meintz, National Renewable Energy Laboratory

Presenter

Andrew Meintz, NREL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

80% of reviewers felt that the project was relevant to current DOE objectives, 20% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 40% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 40% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

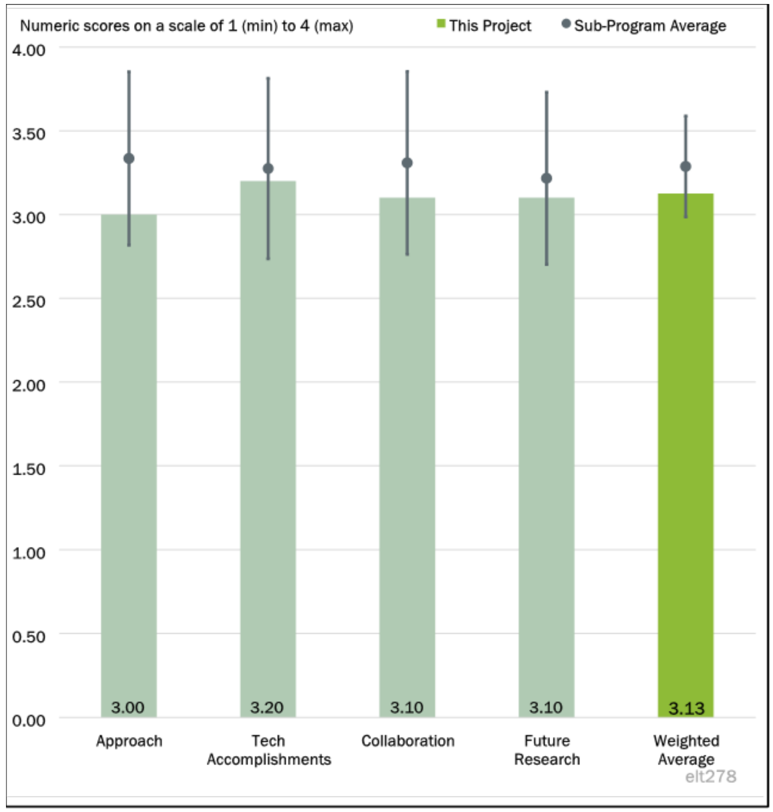

Figure 4-35 - Presentation Number: elt278 Presentation Title: Electric Vehicles (EVs) at Scale Laboratory Consortium Principal Investigator: Andrew Meintz, National Renewable Energy Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

This reviewer said that the approach is very methodical and of long duration. High Power automatic charging should not be ignored. It will be a major part of the future. Drayage, trucks, and buses with large depots need to have high power automatic charging.

Reviewer 2

This reviewer said that the project tackles the disparate threads that make up the charging infrastructure and what is required to make widespread EV adoption feasible. But, the dynamic roadway charging thread seems very speculative compared to the others.

Reviewer 3

Four of the five project areas address significant barriers to EV charging deployment; the fifth, dynamic wireless charging (wireless power transfer [WPT]), is a high-cost solution to address what may or may not be a problem (battery weight). As this project proceeds, the WPT project should address additional implementation barriers to the dynamic wireless approach, specifically standardization of vehicle assemblies to allow for scaling, including having the same standard for static wireless charging, and the metering and billing component—consumption is now measured as part of the data collection, but there also has to be consideration of authentication (what happens if a non-registered vehicle consumes power from the road), how is the metered load being served from the utility reconciled with the total consumption of the vehicles that receive power from that section of the road, and so on. The Codes and Standards activity should be expanded to include open charge point protocol (OCPP), a critical interface between chargers and back-end clouds that is used by the vast majority of charger manufacturers to enable remote monitoring and control, including authentication and payment processing. This standard is required by some states and programs, as well as implied in the NEVI notice of proposed rulemaking, but its further development and improvement would benefit from DOE support, including becoming an ISO standard (it is currently managed by the Open Charge Alliance, which is not a recognized SDO).

Reviewer 4

The timeline makes sense. However, with a new project and any multi-stakeholder process, progress could be expected to slow down.

The reviewer asked a number of questions believing them to be very relevant to the utility space: whether DOE is communicating broadly with utilities that these efforts are underway; whether a dialogue with EPRI would or EEI or both be useful. It seems there are limited opportunities for utilities to engage (one or two utilities per project) but the challenges are industry-wide. Broader communication could be useful in bringing the industry along at speed.

Reviewer 5

This reviewer pointed out that the project is divided into five pillars: vehicle grid integration and smart charging management, high power charging, wireless power transfer, cyber-physical security, and codes and standards. Each of the five pillars has its set of deliverables and due dates. The deliverables and due dates seem satisfactory.

However, the overall weakness of this project is that there does not seem to be a coherence among the five pillars in terms of how they support each or how they relate to each to make a whole. It is as if the five pillars are five separate disparate, distinct tasks with separate, disparate and distinct goals/objectives but with no interdependency with each other (except that they relate to electric vehicles) and thrown thoughtlessly together. Therefore, this reviewer would not say that this is a well-designed project.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer noted that the project is new and just getting rolling, and believed that it has made good progress so far.

Reviewer 2

This reviewer found that the projects are generally on schedule in spite of COVID-19 delays. The project teams have identified and overcome technical barriers successfully and have engaged stakeholders effectively.

Reviewer 3

This reviewer pointed out that it is a long duration program that is just beginning and believed that significant accomplishments have been made for the plan.

Reviewer 4

This reviewer believed that Flexible charging to Unify the grid and transportation Sectors for EVs at Scales' (FUSE) "Grid Impact" needs to be further defined, including whether it is T or D or both and, how customer behavior impacts findings. The reviewer questions whether, if FUSE makes technologically feasible recommendations for smart charge management, those recommendations will be acceptable to consumers and businesses. The end in mind is, according to the reviewer, that society should not be made to feel that they are giving up convenience to drive electric.

For WPT, the reviewer points out that The Ray, a nonprofit in La Grange, Georgia, has already been heavily involved in the space. Allie Kelly is their CEO and the reviewer believes that it would be worth a discussion with her prior to developing a complete project plan.

For the cybersecurity pillar unified national lab collaboration, Plug and Charge is very important as this standard is being proposed in the NEVI program guidance released June 10th. If possible, ISO 15118 lab testing may need to be accelerated due to NEVI implementation should this path be endorsed by the joint office.

Reviewer 5

This five-year project is only six months in progress, so no technical accomplishments have been made.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer said that the project is new but appears well organized amongst the national lab participants but believed that reviewers are somewhat handicapped by not knowing the exact composition of the external advisory council, which seems key to judging the quality of the collaboration.

Reviewer 2

This reviewer noted that the effort requires substantial collaboration and coordination across the labs and with stakeholders in academia, government and industry. The leadership is managing this effectively and achieving broad engagement and stakeholder input. One example is the sharing of data across different models to leverage the benefits of the various modeling efforts (e.g., BEAM). Another example from personal experience is the MCS open standard activity, where literally hundreds of stakeholders have participated in information exchanges and in providing input to the standards development.

Reviewer 3

This reviewer said that, in general, the correct partners have been assessed and are being assigned. It is very important to keep the utilities engaged, including EPRI.

Reviewer 4

This reviewer found that deep collaboration is required for a project of this scope and has already been included in the project plan.

Reviewer 5

This reviewer found that the collaboration and coordination are extremely limited because the only partners are all national laboratories. There are no manufacturers, suppliers or user organizations involved. Even the Federal Highway Administration (FHWA), which is involved with regulating roadways and researching roadway construction techniques, is sorely left out as a partner The reviewer questioned, for example, why this project is evaluating representative asphalt materials when the FHWA Turner-Fairbanks Highway Research Center in McLean, VA is the Federal center of excellence in this very area and why should the national laboratories be duplicating the work of another Federal agency. The reviewer also believed that suppliers and manufacturers of wireless power transfer equipment already in use at two locations, e.g., Antelope Valley Transit Agency and Foothill Transit, have been left out of the picture.

Question 4: Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1

This reviewer found that the proposed future research is excellent. However, these are systemic industry challenges so defined research vs. outcomes will be important to address in future AMR reviews.

Reviewer 2

This reviewer said that the next steps appear promising and touch on the key elements of making EV charging widely available and effective.

Reviewer 3

This reviewer said that the program is just beginning and the team has laid out an excellent future plan but that the program needs to include automated charging for trucks because automated charging in a depot setting is needed and robotics for MCS is not a solution. Power needs with 1400 vehicles for a fleet will be cumbersome without automation.

Reviewer 4

This reviewer suggested that the WPT project would be much more valuable if it addressed commercial as well as technical implementation issues, such as how EV drivers would be billed for charging consumption, how utilities would be reimbursed, who might realistically own the infrastructure and how would they recover their invested capital, etc. The project would benefit from added engagement with EV charging station operators and utilities. The Codes and Standards research should support OCPP. development and evolution, because industry has largely standardized on this protocol already, and its further development is critical to enhancing the efficiency and reliability of EV charging, especially at public stations. While its support for 15118 is a good start, the Codes and Standards research should also consider supporting development of strategies for the transition from 15118-2 to 15118-20, which poses some challenges for the EVSE manufacturers.

Reviewer 5

This reviewer said that the future research in the High-Power Charging pillar of this project seems to have a clear purpose but this reviewer questions the need for this particular pillar of the project. The principal investigator needs to explain why an on-site distribution system should accommodate 1+MW scale charging, LD, MD, HD Long Dwell, LD Short Dwell;, 100kW, and 300kW charging all at the same time. The reviewer asked if the application is targeted for a diversified user such as a rental truck location?

The future research in the Dynamic Wireless Power Transfer in Roadways pillar of this project seems to have a clear purpose but this reviewer questions the need for this particular pillar of the project. The Dynamic Wireless Power Transfer in Roadways pillar of this project appears to duplicate ELT 239, "High Power Inductive Charging System Development and Integration for Mobility," ELT 240, "Wireless Extreme Fast Charging for Electric Trucks," and ELT 197, "High Power and Dynamic Wireless Charging of Electric Vehicles." The reviewer suggested that the principal investigator of this project needs to distinguish this project from the other three ELT projects just mentioned and justify the rationale for duplicate work effort.

The future research for cyber-physical security seems to be targeted for high power electric vehicle charging. However, it is not even clear that high power electric vehicle charging is sufficiently robust and justified to launch widespread use of this technology.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the project supports the VTO electrification initiative to accelerate EV adoption by tackling key issues with charging infrastructure.

Reviewer 2

This reviewer said that there are strong synergies between many of the individual projects within the VTO subprogram and the elements of this project, particularly in the high level system and grid modeling and analysis. This project takes an ecosystem approach that reflects the structure of the EV and EV charging ecosystems to deliver more impactful results overall.

Reviewer 3

This reviewer found that the program is very relevant for the future.

Reviewer 4

This reviewer said that the project supports Electrification specifically.

Reviewer 5

This reviewer said that, although this project touches on the analysis and electrification subprograms of the DOE VTO, this reviewer does not see immediate, widespread needs for high power electric vehicle charging and dynamic wireless power transfer in roadways except in infrequent, specialized niche applications.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the resources appear adequate.

Reviewer 2

This reviewer noted that this a large and complex project but has substantial resources dedicated to it, finding that the approaches, accomplishments (for historical context), near-term tasks, and deliverables are consistent with the overall budget.

Reviewer 3

This reviewer said that the resources are sufficient for the program, but the program is not required, in general.

Reviewer 4

This reviewer said that this is a new project with heavy coordination aspects. Coordination across industry, labs, etc. will only increase as the project stands up workstreams. Unless there is a strong support system already identified now, the reviewer expected that more resources will be required in the near future. Additionally, more resources could be used to communicate on behalf of the project specifically. Or, DOE VTO could contract with other industry partners to bring in additional stakeholders as part of the communication process. The reviewer recommended that the project team think through a communication and stakeholder engagement plan—both with the planned project team, and with industry in general.

Reviewer 5

This reviewer said that $65 million is an excessively high amount for this project. Because a lot of previous effort has taken place, one would expect that taking advantage of that previous effort would bring the total cost down. Unfortunately, the breakdown of resources is invisible, and this reviewer would like to see a breakdown of how those resources will be spent among the five pillars.

Acronyms and Abbreviations

°C	Degrees Celsius
ACM	American Center for Mobility
AMR	Annual Merit Review
BG&E	Baltimore Gas & Electric
BGE	Baltimore Gas and Electric
C	Charge rate
CNG	Compressed natural gas
COVID-19	Coronavirus disease 2019
Cu	Copper
DC	Direct current
DC	Direct-current fast-charging
DWPT	Dynamic wireless power transfer
EDT	Electric Drive Technology(ies)
EDU	Electric drive unit
EERE	Office of Energy Efficiency and Renewable Energy
ELT	Electrification program
EM	Electromagnetic
EPRI	Electric Power Research Institute
EV	Electric vehicle
EVs@Scale	Electric Vehicles at Scale Consortium
EVSE	Electric vehicle supply equipment
EVSP	Electric vehicle service provider
FEA	Finite element analysis
FUSE	Flexible charging to Unify the grid and transportation Sectors for EVs at scale
FY	Fiscal Year
GaN	Gallium nitride
GaN	Gallium nitride
GHG	Greenhouse gas
GM	General Motors
HD	Heavy-duty
HELICS	Hierarchical Engine for Large-scale Infrastructure Co-Simulation

HPC	High-power charging
HRE	Heavy rare earth
IIC	Indiana Integrated Circuits
IIT	Illinois Institute of Technology
IMSwTPG	Insulated metal substrate with thermally annealed pyrolytic graphite
IPM	Interior permanent magnets
ISO	International Organization for Standardization
JBS	Junction barrier Schottky
kV	Kilovolt
kW	Kilowatt
LD	Light-duty
MD	Medium-duty
MOSFET	Metal-oxide semiconductor field-effect transistor
Mph	Miles per hour
MW	Megawatt
MW	Megawatt
NEVI	National Electric Vehicle Infrastructure
NREL	National Renewable Energy Laboratory
OCPP	Open charge point protocol
ODBC	Organic direct-bond copper
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PCB	Printed circuit board
PEV	Plug-in electric vehicle
PHEV	Plug-in hybrid vehicle
PI	Principal Investigator
PM	Permanent Magnet
PNNL	Pacific Northwest National Laboratory
R&D	Research and development
RDD&D	Research, development, demonstration, and deployment
RE	Rare earth
RE	Rare Earth

SAE	Society of Automotive Engineers
SCM	Smart charge management
SiC	Silicon carbide
SNL	Sandia National Laboratories
SSCB	Solid state circuit breakers
SST	Solid-state transformer
SVPWD	Space vector pulse width modulation
TMS	Thermal management system
TOU	Time of use
TVA	Tennessee Valley Authority
U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability
UL	Underwriters' Laboratory
UPS	United Parcel Service
V	Volt
V2G	Vehicle-to-grid
VTO	Vehicle Technologies Office
WBG	Wide bandgap
WPT	Wireless power transfer
XFC	eXtreme fast charging

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5. Materials Technology

The Vehicle Technologies Office (VTO) supports research, development, deployment, and demonstration (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. The office's investments leverage the unique capabilities and world-class expertise of the national laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies and systems (including automated and connected vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement); combustion engines to reduce greenhouse gas (GHG) emissions; and technology deployment and integration at the local and state level. In coordination with the other offices across the Office of Energy Efficiency and Renewable Energy (EERE) and the U.S. Department of Energy (DOE), the Vehicle Technologies Office advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

The Materials Technology subprogram supports the Vehicle Technologies Office goals of achieving 100 percent decarbonization of the transportation sector by 2050. This ambitious goal will be realized through the increased deployment of electric and hydrogen fuel cell vehicles. Materials play an important role in increasing the efficiency of electric vehicles through weight reduction as well as enabling additional functionality such as faster charging and new sensing technologies. Lighter weight vehicle structures and electric drivetrains will require fewer batteries to achieve the same range, which in turn reduces battery cost, material needs, and reduces the GHG emissions from battery production. Functional materials with improved properties such as electrical conductivity, thermal conductivity, and unique sensing capabilities will enable innovations in charging and autonomous vehicles. The materials and manufacturing methods used to make vehicles also contribute to greenhouse gases and the Materials Technology subprogram supports research, development, and deployment to increase recyclability and reduce the overall embodied energy of vehicles. The Materials Technology subprogram accomplishes its technical objectives through research programs with academia, national laboratories, and industry.

Lightweight Materials supports national laboratory, academia, and industry-led 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.

Powertrain Materials supports research at national laboratories, academia, and industry to develop higher performance materials to address the future properties needs of electric and hydrogen fuel cell vehicles to increase efficiency and decrease manufacturing cost, supporting the transition to all electric light duty vehicles by 2035. Research funded through this activity applies advanced characterization and multi-scale computational materials methods, including HPC, to accelerate discovery and early-stage development of cutting-edge structural and high temperature materials for lighter and more efficient powertrains.

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
mat132	High Strength Steel-Aluminum Components by Vaporizing Foil Actuator Welding	Glenn Daehn (The Ohio State University)	5-11	3.00	3.38	3.25	3.50	3.28
mat146	Ultra-Lightweight, Ductile Carbon-Fiber Reinforced Composites	Seokpum Kim (Oak Ridge National Laboratory)	5-14	3.00	3.17	3.17	2.67	3.06
mat149	Shear Assisted Processing and Extrusion (ShAPE) of Lightweight Alloys for Automotive Components	Scott Whalen (PNNL)	5-18	3.50	3.38	3.50	3.33	3.42
mat151	Phase-Field Modeling of Corrosion for Design of Next-Generation Magnesium-Aluminum Vehicle Joints	Adam Powell (Worcester Polytechnic Institute)	5-21	3.17	3.00	3.17	2.83	3.04
mat152	A Hybrid Physics-Based, Data-Driven Approach to Model Damage Accumulation in Corrosion of Polymeric Adhesives	Roozbeh Dargazany (Michigan State University)	5-24	3.63	3.75	3.63	3.25	3.64

mat159	Cost Effective Lightweight Alloys for Electric Vehicle Propulsion: Fundamental Fatigue and Creep in Advanced Lightweight Alloys	Amit Shyam (Oak Ridge National Laboratory)	5-28	3.08	3.42	3.17	2.92	3.24
mat160	Cost Effective Lightweight Alloys for Electric Vehicle Propulsion: Hybrid Dispersion Strengthened Al Matrix Composites for Higher Efficiency Electric Vehicle (EV) Powertrains	Mert Efe (Pacific Northwest National Laboratory)	5-33	3.10	3.20	2.70	3.10	3.10
mat164	Multiscale Development and Validation of the Stainless Steel Alloy Corrosion (SStAC) Tool for High-Temperature Engine Materials	Michael Tonks (University of Florida)	5-37	2.50	2.63	3.00	2.33	2.60
mat174	Carbon-Fiber Technology Facility (CFTF)	Merlin Theodore (Oak Ridge National Laboratory)	5-42	3.50	3.50	3.50	3.50	3.50
mat195	Industrialization of Carbon Fiber Composite Wheels for Automobiles and Trucks	Brian Knouff (Oak Ridge National Laboratory)	5-44	3.25	3.25	3.25	3.00	3.22
mat196	High Temperature Carbon Fiber Carbonization via Electromagnetic Power	Felix Paulauskas (Oak Ridge National Laboratory)	5-48	3.13	3.25	3.13	3.00	3.17
mat197	Multi-Functional Smart Structures for Smart Vehicles	Patrick Blanchard (Ford Motor Company)	5-52	3.75	3.50	3.75	3.50	3.59

mat198	Development of Tailored Fiber Placement, Multi-Functional, High-Performance Composite Material Systems for High Volume Manufacture of Structural Battery Enclosure	Venkat Aitharaju (General Motors Company)	5-55	3.00	3.17	3.50	3.33	3.19
mat199	Ultra-Lightweight Thermoplastic Polymer/Polymer Fiber Composites for Vehicles (Inter-Lab Project)	Kevin Simmons (Pacific Northwest National Laboratory)	5-58	3.00	3.17	3.50	3.33	3.19
mat200	Additive Manufacturing for Property Optimization for Automotive Applications	Seokpum Kim (Oak Ridge National Laboratory)	5-61	3.38	3.50	3.25	3.00	3.38
mat201	Additively Manufactured, Lightweight, Low-Cost Composite Vessels for Compressed Natural Gas Fuel Storage	James Lewicki (Lawrence Livermore National Laboratory)	5-65	2.75	3.00	3.00	3.13	2.95
mat202	3D Printed Hybrid Composite Materials with Sensing Capability for Advanced Vehicles	Rigoberto Advincula (Oak Ridge National Laboratory)	5-69	2.60	2.70	2.90	2.70	2.70
mat203	Low-Cost, High-Throughput Carbon Fiber with Large Diameter	Felix Paulauskas (Oak Ridge National Laboratory)	5-74	3.00	3.17	3.17	3.25	3.14
mat204	New Frontier in Polymer Matrix Composites via Tailored Vitrimer Chemistry	Tomonori Saito (Oak Ridge National Laboratory)	5-79	3.20	3.30	3.20	3.40	3.28

mat205	Adopting Heavy-Tow Carbon Fiber for Repairable, Stamp-Formed Composites	Amit Naskar (Oak Ridge National Laboratory)	5-83	2.88	3.13	2.88	2.63	2.97
mat206	Soft Smart Tools Using Additive Manufacturing	Jay Gaillard (Savannah River National Laboratory)	5-87	3.20	3.20	3.30	3.30	3.23
mat207	Multi-Material, Functional Composites with Hierarchical Structures	Christopher Bowland (Oak Ridge National Laboratory)	5-92	3.50	3.50	2.67	3.33	3.38
mat208	Efficient Synthesis of Kevlar and Other Fibers from Polyethylene Terephthalate (PET) Waste	Lelia Cosimbescu (Pacific Northwest National Laboratory)	5-95	3.25	3.38	2.88	3.00	3.23
mat209	Bio-based, Inherently Recyclable Epoxy Resins to Enable Facile Carbon-Fiber Reinforced Composites Recycling	Nicholas Rorrer (National Renewable Energy Laboratory)	5-99	3.33	3.50	3.17	3.17	3.38
mat210	A Novel Manufacturing Process of Lightweight Automotive Seats - Integration of Additive Manufacturing and Reinforced Polymer Composite	Patrick Blanchard (Ford Motor Company)	5-102	3.25	3.00	3.25	3.25	3.13
mat211	Sustainable Lightweight Intelligent Composites (SLIC) for Next-Generation Vehicles †	Masato Mizuta (Newport Sensors, Inc.)	5-104	3.08	3.00	3.17	2.92	3.03

mat212	Integrated Self sufficient Structurally Integrated Multifunctional Sensors for Autonomous Vehicles †	Amrita Kumar (Accelent Technologies, Sunnyvale)	5-110	3.13	3.25	3.25	2.88	3.17
mat215	Short Fiber Preform Technology for Automotive Part Production †	Dirk Heider (Composites Automation, LLC)	5-114	3.50	2.90	3.20	3.38	3.15
mat216	Low Cost Resin Technology for the Rapid Manufacture of High-Performance Fiber Reinforced Composites †	Henry Sodano (LLC)	5-119	3.50	3.50	3.25	3.38	3.45
mat221	Lightweight and Highly-Efficient Engines Through Al and Si Alloying of Martensitic Materials	Dean Pierce (Oak Ridge National Laboratory)	5-123	3.50	3.33	3.83	3.58	3.47
mat222	Extending Ultrasonic Welding Techniques to New Material Pairs	Jian Chen (Oak Ridge National Laboratory)	5-129	3.25	3.42	3.08	3.00	3.28
mat223	Extending High Rate Riveting to New Material Pairs	Kevin Simmons (Pacific Northwest National Laboratory)	5-135	3.30	3.50	3.20	3.20	3.38
mat224	Solid State Joining of Multi-Material Autobody Parts Toward Industry Readiness	Yong Chae Lim & Piyush Upadhyay (Oak Ridge National Laboratory/Pacific Northwest National Laboratory)	5-140	3.63	3.50	3.63	3.13	3.50

mat225	Surface Modifications for Improved Joining and Corrosion Resistance	Yong Chae Lim & Vineet Joshi (ORNL/PNNL)	5-144	2.88	3.13	2.88	3.00	3.02
mat226	Machine Learning for Joint Quality and Control	Zhili Feng & Keerti Kappagantula (ORNL/PNNL)	5-148	3.25	3.63	3.88	3.25	3.52
mat229	Development of a Novel Magnesium Alloy for Thixomolding of Automotive Components	Govindarajan Muralidharan & Bryan Macek (ORNL/FCA LLC)	5-152	3.17	3.50	3.33	3.00	3.33
mat235	Light Metals Core Program - Thrust 4 - Residual Stress Effects	Ayoub Soulami (Pacific Northwest National Laboratory)	5-155	3.25	3.38	3.38	3.25	3.33
mat236	Advanced Characterization and Computational Methods	Thomas Watkins (Oak Ridge National Laboratory)	5-159	3.25	3.38	3.75	3.13	3.36
mat237	Materials, Lubricants, and Cooling for Heavy Duty Electric Vehicles	Jun Qu (Oak Ridge National Laboratory)	5-163	3.80	3.70	3.60	3.60	3.70
mat238	Advanced Processing and Additive Manufacturing for Electric Vehicle (EV) Propulsion, Ultra Conductor Development for Enhanced EV performance	Keerti Kappagantula (Pacific Northwest National Laboratory)	5-168	3.60	3.60	3.70	3.50	3.60

mat241	Advanced Processing and Additive Manufacturing for Electric Vehicle (EV) Propulsion, Advanced Ceramics and Processing for Wireless Charging Systems	Beth Armstrong (Oak Ridge National Laboratory)	5-173	3.20	3.30	3.20	3.30	3.26
mat242	Advanced Processing and Additive Manufacturing for Electric Vehicle (EV) Propulsion, Novel Ultra High Conductivity Composites for EVs	Tolga Aytug (Oak Ridge National Laboratory)	5-178	3.25	3.42	3.33	3.58	3.39
mat243	Manufacturing Demonstration of a Large-scale, Multi-material Passenger Vehicle Sub-system	Srikanth Pilla (Clemson University)	5-183	2.88	3.00	3.13	3.38	3.03
mat244	LMCP P1A - Sheet Materials with Local Property Variation	Scott Whalen (PNNL)	5-187	3.50	3.67	3.50	3.17	3.54
mat245	LMCP P1B - Form-and-Print - AM for Localized Property Enhancement of High-strength Al sheet	Alex Plotkowski (ORNL)	5-190	3.50	3.25	3.50	3.25	3.34
mat246	LMCP P1C - Local Thermomechanical Processing to Address Challenges to Implementing High Strength Al Sheet	Mert Efe & Govindarajan Muralidharan (PNNL/ORNL)	5-192	3.38	3.25	3.25	3.38	3.30
mat247	LMCP P2A - Solid Phase Processing of Aluminum Castings	Saumyadeep Jana & Zhili Feng (PNNL/ORNL)	5-196	3.13	3.25	3.13	3.00	3.17

mat248	LMCP P2B - High Intensity Thermal Treatment	Aashish Rohatgi (PNNL)	5-200	3.25	3.38	3.38	3.25	3.33
mat249	LMCP P2C - Cast-and-Print - AM for Localized Property Enhancement of Al castings	Alex Plotkowski (ORNL)	5-204	3.13	2.75	3.13	3.00	2.92
mat250	LMCP P3A - Cast Magnesium Local Corrosion Mitigation	Vineet Joshi & Jiheon Jun (PNNL/ORNL)	5-208	3.50	3.38	3.50	3.38	3.42
mat251	LMCP P3B - Thermomechanical Property Modification of Mg Castings	Mageshwari Komarasamy (PNNL)	5-212	3.38	3.25	3.25	3.13	3.27
mat252	LMCP - Thrust 4 - Materials Lifecycle	Jeff Spangenberg-er (Argonne National Laboratory)	5-217	2.00	2.38	2.75	2.50	2.34
mat253	Flexible, Lightweight Nanocomposites for EMI Shielding Suppression in Automotive Applications †	Carla Lake (Applied Sciences)	5-221	3.17	3.00	3.67	3.25	3.16
mat255	Graphene-enriched Hierarchical Polymer Additives Derived from Natural Gas †	George Skoptsov (H. Quest Vanguard, Inc.)	5-224	3.30	3.10	3.00	3.10	3.14
mat256	Game Changing Resin/Coating/Adhesive Technology for Lightweight Affordable Composites †	Scott Lewit (Structural Composites, Inc.)	5-230	3.00	2.70	3.20	2.80	2.85
mat257	Changing the Design Rules of Rubber to Create Lighter Weight, More Fuel Efficient Tires †	Kurt Swogger (Molecular Rebar Design, LLC)	5-235	3.50	3.42	2.50	3.30	3.31

mat258	Hierarchical Micro/Nano Reinforced Multiscale Hybrid Composites for Vehicle Applications †	Shawn Beard (Advent Innovations, LTD)	5-240	3.20	3.20	3.40	3.13	3.22
Overall Average				**3.21**	**3.25**	**3.24**	**3.15**	**3.23**

Presentation Number: mat132
Presentation Title: High Strength Steel-Aluminum Components by Vaporizing Foil Actuator Welding
Principal Investigator: Glenn Daehn, The Ohio State University

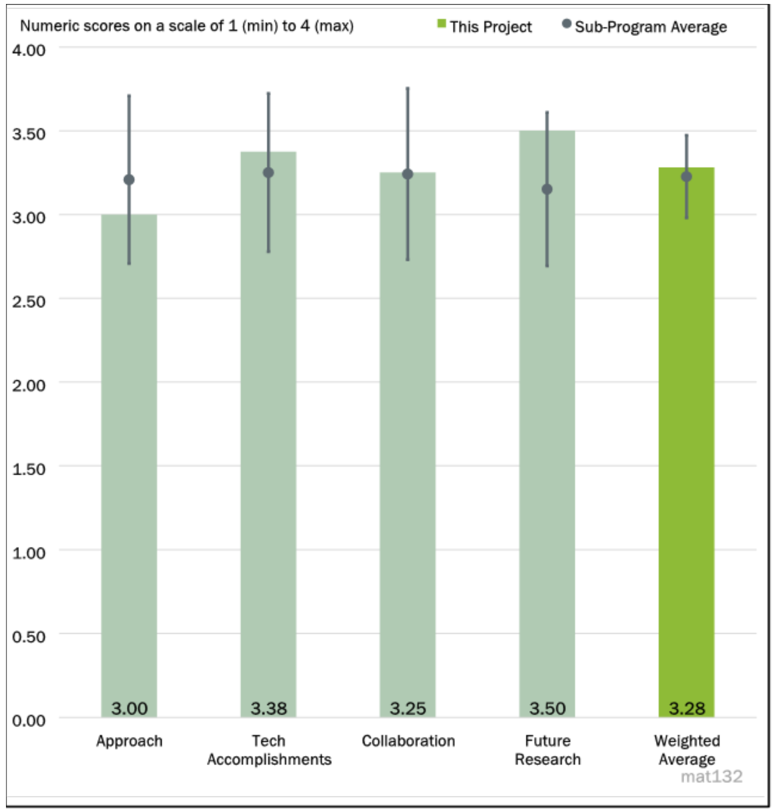

Figure 5-1 - Presentation Number: mat132 Presentation Title: High Strength Steel-Aluminum Components by Vaporizing Foil Actuator Welding Principal Investigator: Glenn Daehn, The Ohio State University

Presenter

Glenn Daehn, The Ohio State University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 2

The project approach of including lab coupon evaluation, component/assembly finite element analysis (FEA), prototype build, and test to validate a new joining process is an outstanding approach. Corrosion evaluation of the completed assembly (especially since galvanic corrosion can be far more complex on assemblies than on simple coupons) would be good to consider.

Reviewer 2

The approaches are appropriate in terms of process and part design, fabrication, and validation. The in-depth analysis was not given in this presentation probably due to limited time.

Reviewer 3

Considering its infancy as a demonstrated technology, there is room for further growth before eventually being in the commercial manufacturing process.

Reviewer 4

Project barriers were highlighted as cost and mass savings, but these are the motivation and should not be construed as the technical barriers. This project is really a process development project, and as such the technical barrier is to increase the Manufacturing Readiness Levels (MRL).

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This project demonstrated that variable frequency arc welding (VFAW) can successfully weld stamping grade Al and steel pair in Al thickness relevant to sub-frame structures.

Reviewer 2

The reviewer said technical accomplishments are substantial and support the overall project approach very well.

Reviewer 3

The project has met the goal and achieved all the milestones.

Reviewer 4

The project worked to achieve quality welds for a given stack-up with no investigation of process robustness, i.e., process variables such as off-angle, variable sheet metal, or coating thickness, etc. However, the intended MRL was not indicated. It is unclear about the quality of welds on the subframe to meet the product performance requirements.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

It appears that the collaboration was well coordinated between partners. The reviewer was pleased to see a machine builder and targeted end user included as partners.

Reviewer 2

The collaboration and coordination across the team are good.

Reviewer 3

The project team consists of Ohio State University (OSU), Pacific Northwest National Lab (PNNL), Magna, Cold Water Machine Company, Ashland, and Arconic. However, the role of each team member was not clear.

Reviewer 4

The project benefits from great collaboration and cooperation among a group of participants with complementary areas of expertise. It was unclear about Ashland/Bostik team role in the project since there was no mention of their work in the presentation.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer remarked the challenges and barriers are well identified. OSU is the expert in the research of VFAW.

Reviewer 2

The reviewer said remaining challenges and barriers have been clearly identified.

Reviewer 3

The project has ended.

Reviewer 4

The project has ended and so there is no future work plan.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

DOE is interested in GHG emission reductions. Application of lightweight materials supports this goal. In order to actualize application of the right material in the right form in the right application, it is imperative to achieve dissimilar material joints which this project supports.

Reviewer 2

Joining of dissimilar materials is a critical area in advanced manufacturing for DOE to reduce the structural weight and improve component performance and energy efficiency.

Reviewer 3

The project is focused on developing joining technology to enable increased use of Al in vehicles currently produced primarily of steel. The estimated cost ($14/kg saved) reported for Design 2 exceeds VTO objectives. It is likely that with fewer VFAW welds and greater weight reduction, the cost for Design 1 would be considerably lower and likely well below the VTO objectives.

Reviewer 4

The project is very well-aligned with the VTO objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The project team did not achieve their intended milestone of Design and Build of a robotic welding system due to delays related to trouble shooting and coronavirus disease of 2019 (COVID). The milestone could have been accomplished if additional qualified were available under the COVID situation.

Reviewer 2

The team has sufficient recourses including hardware and software to deliver the milestones on time.

Reviewer 3

Resources are well planned and utilized throughout the project, with the possible exception of Ashland/Bostwick whose work was not presented.

Reviewer 4

The project has the appropriate resources to execute the project.

Presentation Number: mat146
Presentation Title: Ultra-Lightweight, Ductile Carbon-Fiber Reinforced Composites
Principal Investigator: Seokpum Kim, Oak Ridge National Laboratory

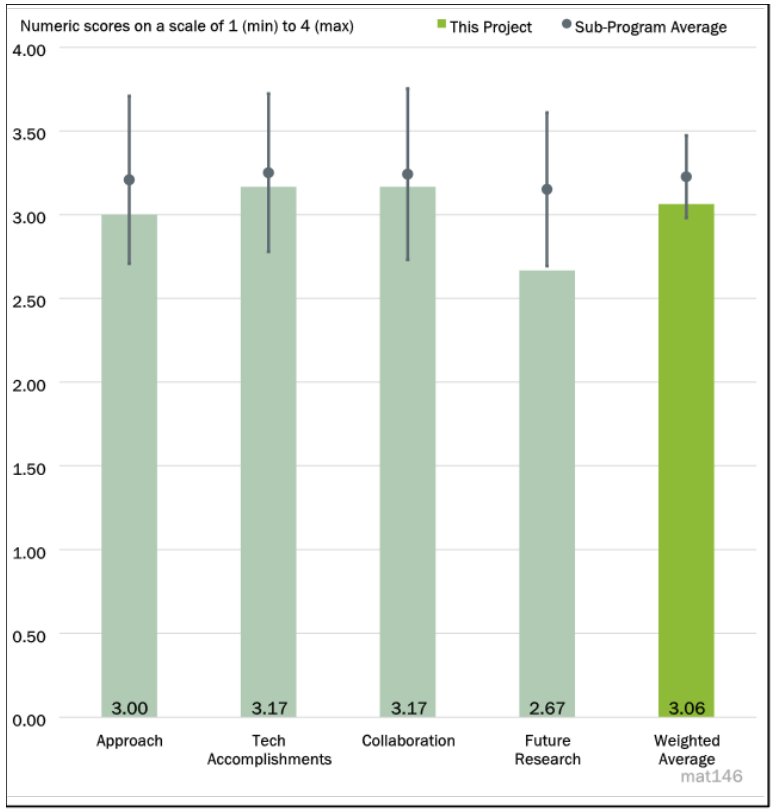

Figure 5-2 - Presentation Number: mat146 Presentation Title: Ultra-Lightweight, Ductile Carbon-Fiber Reinforced Composites Principal Investigator: Seokpum Kim, Oak Ridge National Laboratory

Presenter

Seokpum Kim, ORNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The project has addressed the need for lightweight, high mechanical performance materials through development of serially photo-printed engineered structures. The barriers of production speed and resolution versus part size, defined within the project, have been addressed through optimized scanning, development of new fixtures, etc. The industry and DOE barriers of material cost and part production time are not meaningfully addressed in this project. An extremely lightweight part that takes hours to print and is made of expensive photo-curing resin demonstrates scientific proof of principle but does not contribute to near- or medium-term reduction in fuel use or carbon dioxide emissions in the U.S. transportation sector. The technology is too expensive to be implemented at a scale that will reduce emission goals.

Reviewer 2

The team is addressing the challenge by considering a variety of aspects including materials, design, and equipment. Consideration of specific project goals with measurable metrics (e.g., percentage improvement of mechanical properties) has been encouraged.

Reviewer 3

The team has made good progress on a complex system for both the additive manufacturing (AM) system development and slicing, and the materials development into an extrudable ultraviolet (UV) curing system. The technical barriers have continued to advance as the team works to improve fiber alignment and feature resolution. It was difficult to determine whether the project was an AM technology development project or a materials development project as the overall objective states “Create hybrid hierarchical materials that are ultralight, strong and tough for 3-D printing.” However, the summary slide does mention AM in “Target: Develop an AM technology for hybrid hierarchical carbon fiber (CF)-reinforced materials that are ultralight, strong and tough for 3D printing.” This statement was more in line with what was presented, and progress was made on both the AM system and the materials. An understanding of the fiber length effect in relation to feature size to determine the limitations of fiber lengths and expected orientations would be useful. Continuation of processing parameter development for fiber orientation is planned. Fiber aspect ratios relative to feature size being printed need to be also considered.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

There has been great technical progress in both the development of a larger AM system and in materials processing. The move to extrusion based cured system to improve fiber alignment showed significant progress. New plate like features added new dimension to the properties of the structure. The multi material plate structure was a significant new advancement providing excellent dampening features to the improved absorbed energy.

Reviewer 2

The team demonstrated good mechanical property and printing rate improvements. The project seems to be on track.

Reviewer 3

Print speed and resolution vs. part size have been improved through technical progress. Attempts were made to consider fiber loading and alignment, but degree of alignment was not quantified and only considered qualitatively. A key past reviewer had commented on the need for a comparison of this part technology performance with performance of alternative technologies. Performance comparisons including print area, resolution, stiffness, and strain of this work seem to be made relative to other photo-based AM technologies. A meaningful comparison of production time, cost, and performance of the project technology would be versus materials and production methods currently used in U.S. vehicle production such as injection molding, compression molding, vacuum assisted resin transfer molding (VARTM), sheet molding compound, and bulk molding compound. Comparison of a laboratory technique to a laboratory technique does not inform how it compares to the state of the auto industry.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer praised the good collaboration and coordination between Oak Ridge National Laboratory (ORNL) and University of California at Los Angeles (UCLA). An inquiry was made about the collaboration with Tier1 suppliers or original equipment manufacturer (OEMs) including any OEM interest in implementing the outcome of this project.

Reviewer 2

The team collaboration is clearer this year as the presentation clearly identified the responsibilities of each team. The team was working together to develop the AM system and the materials structure research. The integration of the two team roles is important to make the system work and the requirements of the material performance in the new system design.

Reviewer 3

The team has the right technical expertise. The reviewer suggested including a user of the technology at least as a consultant in the team.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer suggested achieving localized fiber alignment for optimizing part design. Product demonstration of a full-size auto part (bumper) is interesting to connect the technology to the real need, but it may be infeasible for the bumper that may take 200 hours to print. The designed part demonstrates scientific proof of concept with the incorporation of sensing, but it is unclear how it will reduce material costs and decrease required production time for an adequate mechanical performance lightweight vehicle material.

Reviewer 2

The reviewer suggested a better understanding of the cost structure to determine the right applications.

Reviewer 3

The first two bullets on the future research slide are well aligned and are appropriate for further developing the research. However, the last bullet seems to be out of scope from the stated target of creating a hybrid hierarchical material that are ultralight, strong and tough for 3-D printing. The printing and testing of self-sensing structure do not appear to be part of the project scope based on the slides and the presentation discussion. The project should focus on the first two bullets in their future research slides and not dilute the project with out-of-scope elements.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said the project is related to vehicle light-weighting and sustainability.

Reviewer 2

The project is working on the development of lightweight and energy absorbing structures. The structures are complex and would be difficult to mold in traditional systems. The project has demonstrated both energy absorbing and sound dampening. This is inline the Materials program in lightweighting vehicles.

Reviewer 3

This project addresses neither of two major polymer composites goals, i.e., low-cost materials and high throughput manufacturing.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The team has done excellent work and have significant progress in meeting and exceeding their milestones. The work completed was also during more challenging times with COVID.

Reviewer 2

The throughput (printing speed) of the project has doubled in the last year. This is impressive, but it means that perhaps the part that took 50 hours to print can now be printed in 25 hours. There are not sufficient Available timeframe and funding in the project is insufficient to achieve industry and DOE-targeted part production rate of within a few minutes per part.

Reviewer 3

Project has sufficient support.

Presentation Number: mat149
Presentation Title: Shear Assisted Processing and Extrusion (ShAPE) of Lightweight Alloys for Automotive Components
Principal Investigator: Scott Whalen, Pacific Northwest National Laboratory

Presenter

Scott Whalen, PNNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

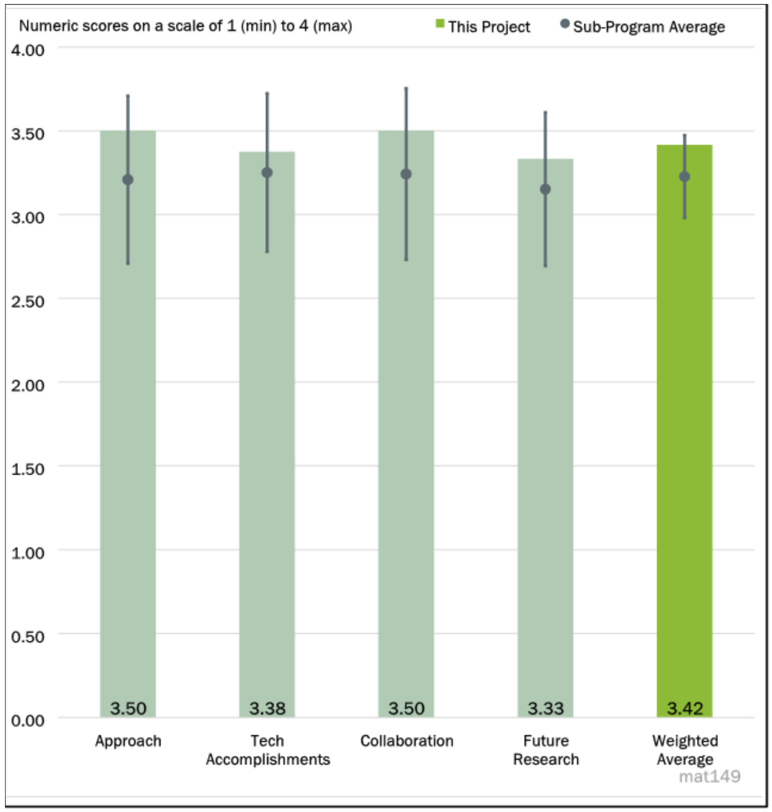

Figure 5-3 - Presentation Number: mat149 Presentation Title: Shear Assisted Processing and Extrusion (ShAPE) of Lightweight Alloys for Automotive Components Principal Investigator: Scott Whalen, Pacific Northwest National Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The project appears to have established strong parameters and settings to achieve good results for the 100% Al scrap aspect of the project. Porthole dies were demonstrated with no discernable seams that met production speeds as well as ASTM standard material properties in industrial heat treatments. The study on Mg (ZK60) did indicate the process could improve effects of texture but not at the required production speeds, thereby contributed to only good empirical data. This project has successfully demonstrated the goals and appears to be able to complete on time.

Reviewer 2

The reviewer noted this is the last year of this project. The project has achieved its objectives.

Reviewer 3

The work on using Al chips to make extrusions has both technical and environmental benefits. However, the technical barrier to Mg alloy ZK60 has not been addressed.

Reviewer 4

The reviewer said the four-year project is well executed as all aspects of Al extrusion were evaluated. The project evaluated simple and complex shapes, and virgin and recycled material. However, more efforts to evaluate the process for Mg could have been useful.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The project demonstrated the initial capability of using the Shear Assisted Processing and Extrusion (ShAPE™) process for 100% Al scrap. These results demonstrated sufficient promise that their commercial partner is pursuing the ability to take to production, and thereby the success of the project technical goals was achieved. The question of the application of this process for improvements of mechanical characteristics of ZK60 was also answered, but not at industrial speeds. The project also delivered a set of extrusion limits for ZK60 under this process, the data that can be used in a future study, if needed.

Reviewer 2

The progress on Al extrusions is impressive, but the same cannot be commented on Mg work.

Reviewer 3

The ability of the Shear Extrusion process to extrude Al and Mg tubes was evaluated. The project showed that Al alloy can be extruded well, even though at lower speeds than direct extrusion process. One advantage is that the ability to extrude solid briquettes consists of Al scarp rather than virgin material. This is beneficial to reduce energy footprint as well recyclability. The problem of texture as the major reason for not continuing the research on that material is also there in conventional extrusion process. The direct or hydrostatic extrusion process could have been tested to reduce the texture issue. More research on Mg in future may reveal usefulness of this process.

Reviewer 4

The milestones were met, and potential for commercial application with environmental gain was demonstrated for the Al alloy. No significant improvements for Mg-alloy were demonstrated.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The technical team clearly utilized industry input in determination of feasibility of this process for industrialization in their metrics.

Reviewer 3

The excellent collaboration between the partners was demonstrated as Magna had obtained license to commercially operate this process for automotive applications.

Reviewer 3

The support from industry is strong. The reviewer suggested some support from universities, especially in Mg alloys.

Reviewer 4

The contributions from the lab and industry were clear with effective synergy.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The effects of other alloys and contaminants in the recycling stream is recommended as a necessary next step towards the expansion of work. The focus on optimization of the briquettes is also important. It is a good decision in winding down any further project focus on Mg.

Reviewer 2

The proposed work for the remainder of the fiscal year is clear and very likely to achieve it within the time left.

Reviewer 3

The project is almost completed. I personally believe there is more work can be done on Mg alloys, perhaps with support from universities with strong expertise in Mg alloys.

Reviewer 4

No new work is proposed as it the last project year. A new project could be initiated to further explore the process for Mg.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This technology can serve as an enabler for utilizing secondary Al scrap in wrought applications.

Reviewer 2

The project is supporting the vehicle lightweighting goal.

Reviewer 3

The major impact of this project is the reduction in the energy and carbon footprints of manufacturing process by using the recycled material. Using low-cost lightweight material will enhance the use of Al in automobiles which can result in reduced weight and improved energy efficiency, thereby will contribute to the objectives of DOE.

Reviewer 4

The project goals support the VTO program goals. It demonstrated sustainability in extrusion technology.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The project only has a few more months to go and there appears to be sufficient resources to complete.

Reviewer 2

No request for additional resources was made at the end of project.

Reviewer 3

Resources are sufficient for completion.

Reviewer 4

The reviewer had no comments.

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 three reviewers evaluated this project.

Project Relevance and Resources

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

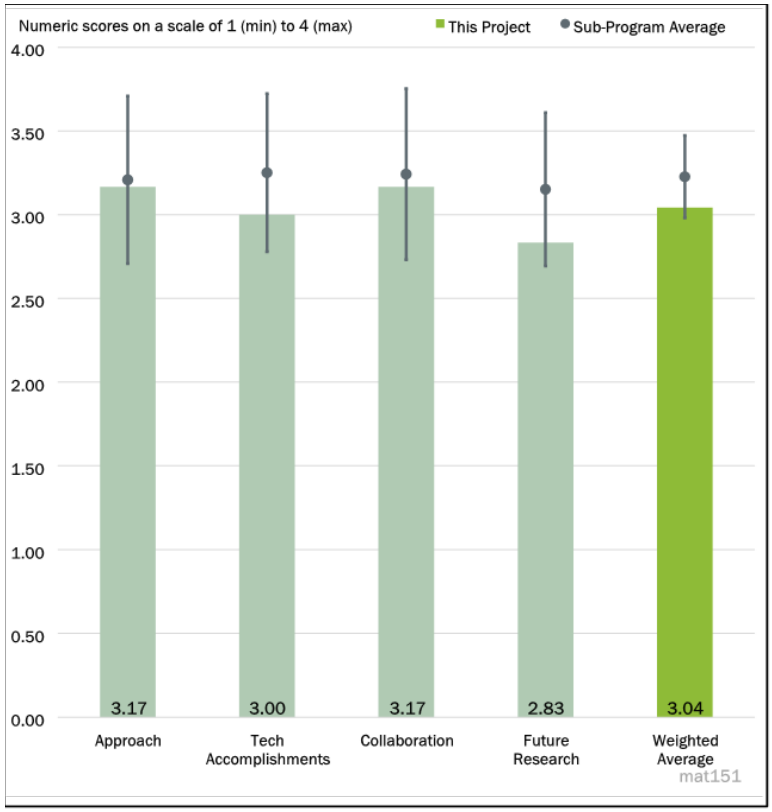

Figure 5-4 - Presentation Number: mat151 Presentation Title: Phase-Field Modeling of Corrosion for Design of Next-Generation Magnesium-Aluminum Vehicle Joints Principal Investigator: Adam Powell, Worcester Polytechnic Institute

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The project team has accomplished a lot to further understanding of this joint type in spite the ambitious project scope. The project is well focused on the critical barriers. The combination of modeling and experimental work is providing a holistic approach.

Reviewer 2

It may be advantageous to extend the corrosion cycle out beyond the normal 8 weeks duration in order to introduce significant corrosion which can then be used for correlation. A plan to include charge transfer resistance is in place to address this issue of the higher simulated oxidation rates than the experimental values. The Mg corrodes by pitting and the modeling is based on this though the location of pit initiation sites is done manually. It was recommended to be able to predict the sites of pitting as part of the corrosion model.

Reviewer 3

The work was very clear and executed carefully. The research area is somewhat unconventional as it seems noncommittal between fundamental and applied work. The work could have more overall impact if a side were chosen.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

Excellent progress has been made. Potentially some further work could be done on understanding the role of microstructure in joint failure.

Reviewer 2

The team has made good progress in the technical challenges given the limitations of COVID. The team is cognizant of the remaining key challenges and have a plan in place to reach their goals.

Reviewer 3

This project shows that considerable and very good work is being done.

Question 3: Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1

The project leverages the strength of each partner: PNNL for the friction stir welding (FSW), ORNL for the microscopy, and Worcester Polytechnic Institute for the Phase Field modeling.

Reviewer 2

Collaborators appear to be well coordinated in this project.

Reviewer 3

There is clearly good teaming. It is unclear about the auto industry engagement at this point with one of the team members moved to PNNL More connections for the industry applications would be valuable.

Question 4: Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1

The team recognizes the remaining technical challenge (i.e., integrating the charge transfer resistance to the electrochemistry model) and thereby is focused on developing this in the remaining time in the project. In addition, coupling the mechanical performance to the electrochemistry model is planned.

Reviewer 2

The project plan forward seems appropriate as it is nearing end.

Reviewer 3

In the final months of the project, the team will be completing their modeling of corrosion/fracture in the FSW joints. It would be good to see a future work plan that indicates a more explicit path forward to fully integrate the various characterization tests and findings—for example, the work involved in understanding fracture in the context of grain size and micro- and nano-hardness maps. In the case of the micro- and nano-hardness data, it appears that some promising and interesting experimental work was done, but this is not yet being fully leveraged in models and it is not clear how this will be leveraged. Future work plans also do not explicitly include study of grain size effects despite this being a suggestion from reviewers in the last 2 years of reviews. The reviewer suggested that the project team will continue to consider these important aspects as they complete their project and final report.

*Question 5: **Relevance: Does the project support the overall VTO subprogram objectives?***

Reviewer 1

Application of lightweight materials supports the goal of DOE interest in GHG emission reductions. It is imperative to achieve dissimilar material joints to materialize application of the right material in the right form in the right applications. The impact of corrosion on mechanical performance is necessary for the implementation of dissimilar material joints.

Reviewer 2

Corrosion of ultra-light materials is clearly important for future vehicles and in scope for DOE.

Reviewer 3

The project is well aligned with DOE objectives in multi-material joining and corrosion mitigation.

*Question 6: **Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?***

Reviewer 1

The project was well resourced for the friction stir welding portion although the bulk of the challenging work remains in the modeling portion. Additional resources could be used here to achieve the final metric in the allotted time.

Reviewer 2

This project is sufficiently supported for the objectives.

Reviewer 3

Resources are sufficient.

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

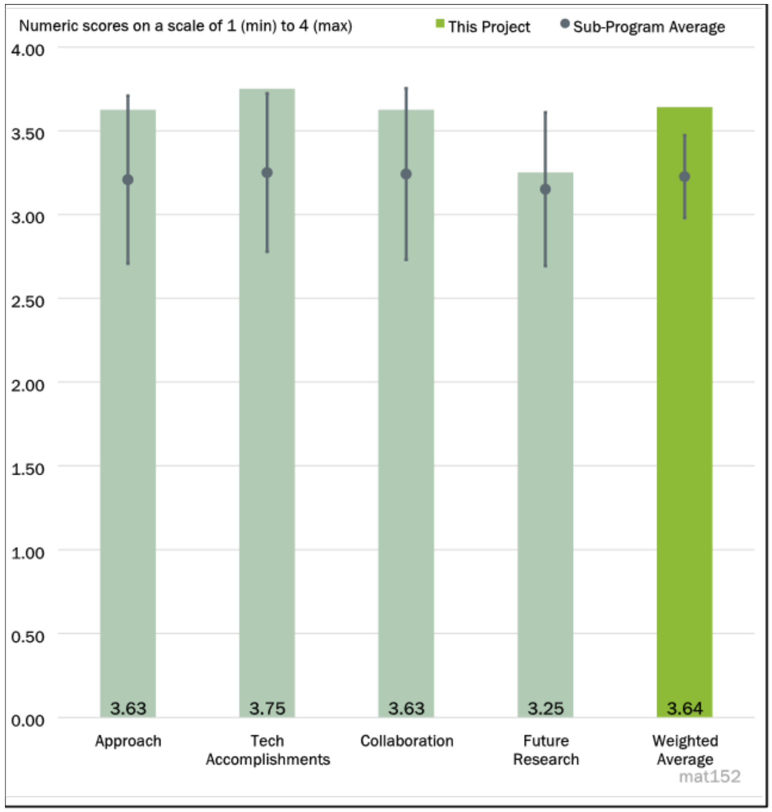

Figure 5-5 - Presentation Number: mat152 Presentation Title: A Hybrid Physics-Based, Data-Driven Approach to Model Damage Accumulation in Corrosion of Polymeric Adhesives Principal Investigator: Roozbeh Dargazany, Michigan State University

Presenter

Roozbeh Dargazany, Michigan State University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The approach for addressing primary technical barriers is well designed because it includes the individual damage mechanisms of deformation, vibration, and oxidation due to thermal, UV, hydrolysis, and combinations of these mechanisms. The approach follows a logical path for derivation of individual models, validation of those models, and training/fitting of a neural network engine. The timeline for accomplishing the work is timely and appropriately designed to accomplish the stated goals of the project. The approach also involves the project partners (Bosch and Endurica, LLC) at the appropriate levels within the project schedule to be effective in achieving the desired outcome of the research. There has been the lack of constitutive models to predict the effects of corrosion and accurate predictive modeling tools for addressing barriers. A significant challenge to the approach is obtaining the necessary test data for validating the test protocols to obtain data that will provide the desired prediction error of less than 10%. This will probably be improved using the data to be obtained in the last year of the project.

Reviewer 2

This program has a clear focus on the important problem of the aging of polymers. It is physically based and developed useful neural net approaches and reduced-order models. The publication history shows that this program is productive and aligned with contemporary science.

Reviewer 3

The project approach appears to be a logical approach to meet the stated goals of developing a theoretical model to describe damage accumulation with respect to deformation, vibration, hydrolysis, thermo-oxidation, and photo-oxidation as well as developing software to predict failure of cross-linked polymeric adhesives with respect to damage caused by environmental and mechanical loads.

Reviewer 4

The current project approach appears to be working, but it is hard for the reviewer to understand and follow. It is difficult to identify the 'physics' component of machine learning (ML) as it appears rather conventional analytical modeling to the reviewer. It is also unclear how the properties of unknown compounds will be predicted from the artificial intelligence (AI) surrogate model, which is outside of the boundary condition.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The technical accomplishments for the modeling have been outstanding. A sound, fundamental scientific approach was used for individual models and the achievement reported for the thermo-mechanical model for failure prediction to be the first ever validated model that covers permanent set and relaxation. The theoretical equations used for the models to predict a combination of effects (thermal, UV, and mechanical) were very effective for prediction this type of failure mode as observed by the data used to validate the models. The model for the effects of hydrolysis on joining materials such as silicone and polyurethane compared very well with the experimental data presented. Aging effects for these materials were well predicted by the models developed. The results for the ML training were very good at lower temperatures (60°) but seem to deviate significantly at the higher temperature (95°). More iterations may be necessary to get better results at the higher temperatures. For the three 3 that work has been performed, the progress has been very good, and the modeling appears successful to date.

Reviewer 2

Collaborations and publications highlight strongly to the impressive accomplishments of this program.

Reviewer 3

All of the work reported in the presentation appears to have been successful in meeting the stated project goals. The project is 90% complete and all of the milestones but one has been completed.

Reviewer 4

The project has made a good progress of the original proposed schedule/milestones.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The mix of performers is excellent for this type of research (materials modeling). Project partners included academia, a Tier 1 producer, a lightweighting consultant, a testing company, a research center, and a separate material modeling group. The project collaboration could only be improved if the project team included an automotive OEM who would be exposed to the benefits of the models being developed. The organizational diagram on Slide 20 illustrates an effective, coordinated effort, and details of the coordination and collaboration are evident in the slides on the technical accomplishments.

Reviewer 2

There is a clear collaboration of many partners, and their contributions are clear.

Reviewer 3

The project includes a good selection of partners with complementary areas of expertise to conduct research, produce software modules, and to implement the models in adhesive joint design.

Reviewer 4

The project team consists of university and industry partners, which shows a good collaboration.

*Question 4: **Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?***

Reviewer 1

Program is nearing end, but on good path.

Reviewer 2

The proposed future work appears to be a logical and complementary continuation of the completed work.

Reviewer 3

The proposed future research is good and appropriate.

Reviewer 4

The proposed future research only addressed what would be done in the remainder of the project; primarily studying degradation mechanisms of the bulk adhesive to other material substrates. It should also include any proposed research beyond the current project efforts. This was also stated on the response to previous year review comments slide. Follow-on future research could also include expanding to other adhesives used by automotive manufacturers.

*Question 5: **Relevance: Does the project support the overall VTO subprogram objectives?***

Reviewer 1

The project is relevant to supporting overall VTO subprogram objectives as stated on Slide 2 and referenced with the Light Duty Workshop Final Report and U.S. DRIVE Materials Technical Team (MTT) Roadmap, Section 5.1 which addresses the use of mixed material systems for lightweighting solutions, and Section 6 for high-priority research needs for modeling and response prediction of composite materials and accurate predictive tools for multi-material systems.

Reviewer 2

The project addresses clear topic of central interest.

Reviewer 3

The project addresses lack of reliable joining technology for dissimilar materials as well as cost-effective tests for adhesive corrosion by creating a constitutive model for predicting corrosion and damage accumulation of adhesive joints. It facilitates use of lightweight materials for vehicle mass reduction by helping to accelerate design of composite joints in vehicle structures and reducing time/cost for testing corrosion failure.

Reviewer 4

The research project supports the overall VTO objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The project funding is around $1.5 million with a 33% cost share by the non-government companies. This is sufficient funding for the three primary performers, i.e., Mississippi State University (MSU), Bosch, and Endurica LLC with minimum support and consulting from the other collaborators.

Reviewer 2

Good level of support has been provided to the project.

Reviewer 3

The project is 90% complete and appears to be on budget and meeting all of its previously defined goals.

Reviewer 4

The overall DOE funding level is a bit excessive for a university to perform only theoretical tasks.

Presentation Number: mat159
Presentation Title: Cost Effective Lightweight Alloys for Electric Vehicle Propulsion: Fundamental Fatigue and Creep in Advanced Lightweight Alloys
Principal Investigator: Amit Shyam, Oak Ridge National Laboratory

Presenter

Amit Shyam, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

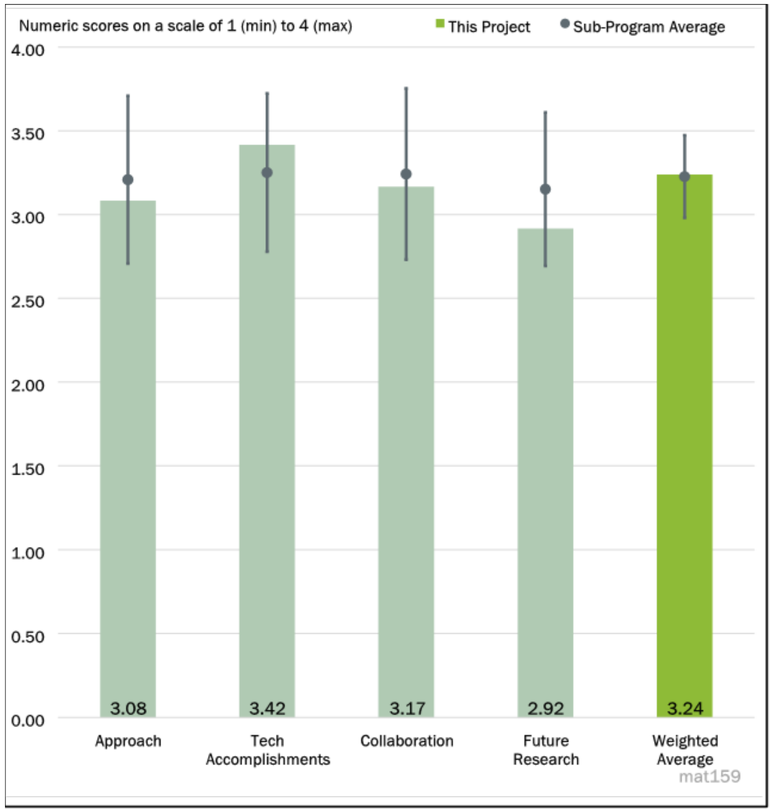

Figure 5-6 - Presentation Number: mat159 Presentation Title: Cost Effective Lightweight Alloys for Electric Vehicle Propulsion: Fundamental Fatigue and Creep in Advanced Lightweight Alloys Principal Investigator: Amit Shyam, Oak Ridge National Laboratory

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The project tasks are well designed to obtain fatigue and creep performance of selected alloys. The collaboration with Northwestern University team to bring in expert on creep behavior benefit the project significantly.

Reviewer 2

The project appears to be well designed. One of the central themes in the project title is “cost effective,” which is consistent with VTO’s goals. As no cost analyses components are called out in the task list, it needs to be called out instead of it may be buried in the task list as a subtask. A better understanding by the PIs of the likely operating conditions/temperature range of the component(s) being fabricated based on engineers in auto companies would be useful. This will prove invaluable in helping the PIs gauge whether their alloys will operate effectively as brake rotors or other components of interest after deployment in the field.

Reviewer 3

A literature search by the investigators on the past research and implementation in this space to understand past challenges to widespread adoption of Al brake materials would be useful. An understand of differences between internal combustion engine (ICE) and BEV vehicles will enable the use of Al brakes in electric vehicles (EVs) that previously did not meet all necessary attributes.

Reviewer 4

It appears that there has not been much of a change in the work, even though the application has completely changed. Brake rotors and conductors have very different conditions than the previous work. As modern materials design approaches tailor the material to the application, which cannot be applied without spending time on the understanding of its applications. Starting with alloys from the past work makes sense, but more time needs to be spent right from the start to understand the new performance requirements.

Reviewer 5

The project timeline appears appropriate unless brake validation is required. The exact requirements for the brake application are not mentioned. The author should get specific requirements from the automotive OEMs to confirm that the limiting requirements are indeed fatigue and creep. This should then be related to the maximum sample testing temperature and duration. The function of thermal conductivity and yield strength is important and needs to be captured since changing alloy can have an influence on them. Good physical metallurgy research is being undertaken but connection to product requirements could be strengthened.

Reviewer 6

The microstructural evaluations are very supportive of the results being presented. More specific project definitions (with specific regard to application-based needs and constraints) would be extremely valuable in providing a more suitable vantage point for critical review.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

Great progress has been made so far. Additional results on particle stability, as the intermetallic population is resistant to elevated temperature evolution including theta particles would be desirable. These kinetic responses may become a concern depending on the expected operating temperatures.

Reviewer 2

The project team carried out detail microstructure characterization and correlate the observation with the performance (creep and fatigue). The quality of the work is high.

Reviewer 3

The technical progress of work has been good and appears to be in line with the planned work. Major schedule delays are not apparent.

Reviewer 4

The results reported were limited as compared to the amount of work which was cited to have been completed.

Reviewer 5

The authors demonstrate excellent microscopy and understanding of the mechanisms.

Reviewer 6

The technical work on fatigue and creep is valuable and interesting. However, it does not clearly address the new applications. This project has struggled to pivot to the new applications.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer noted that some outside involvement was identified, such as mechanical testing done elsewhere. Leveraging Advanced Manufacturing Office (AMO) funding is also a reflection on the project management efforts and involving highly regarded manufacturing demonstration facility (MDF) research & development (R&D) capabilities.

Reviewer 2

The reviewer said the project team consists of multiple national laboratories and top-notch universities which brings in external experts to the project.

Reviewer 3

Northwestern is an excellent partner. It is imperative that the project needs to include a brake OEM, even at this stage of the project as a “no-cost” partner. Brakes are a highly engineered system, and the applications is not trivial.

Reviewer 4

Listed partners listed include PNNL and Northwestern University Prof. David Dunard. PNNL is the only organization listed in the Task table on Slide 3 and the role of Argonne National Laboratory (ANL) as an external partner is unclear without any mention of it on this slide or in the chart on Slide 18, in spite of its logo appears on Slide 2. Similarly, the role of Prof. Dunard is unclear. ORNL seems to be doing the bulk of the work, from the budget table presented on Slide 3. It would be helpful to have a better understanding of the collaboration synergies in the future.

Reviewer 5

Collaborations were clearly discussed and seem reasonable.

Reviewer 6

More industrial collaboration/benchmarking is needed to help target this research.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The work plan will likely achieve targets.

Reviewer 2

The reviewer said the future research addresses the appropriate areas but needs to be clearly defined in terms of ultimate targets. The research is appropriate from a fundamental materials science standpoint, but would benefit from specific ties application-based targets.

Reviewer 3

The proposed work is fine.

Reviewer 4

The tasks proposed seem to be all related to property characterization and mechanism study. It is not clear how the project team is going to address the barrier "property requirements for specific EV applications" which remains to be clearly defined.

Reviewer 5

The future research plan indicated its contribution towards achieving the overall project goals. The plan may consider the following issues: cost analyses of the material(s)/component(s); increased effort on the understanding of the operating ranges of the target components for the alloys being developed (this information might precipitate an adjustment of the temperature at which creep testing is conducted); corrosion testing mentioned in the task list, but not highlighted in the future work; and no mention of measurements or improvements in electric property data for the materials being developed.

Reviewer 6

The reviewer suggested the authors consider other requirements after understanding the brake system. Information on brakes from the literature could be used if unavailable from OEMs. Al brakes have been studied in the past.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said this project is a good program. The line between lightweighting and EV range seems reasonably obvious, but a quantification of targets based on specific criteria for brake rotor systems is not clear. Creep and fatigue resistance are certainly a starting point.

Reviewer 2

The project clearly supports the DOE goal for materials.

Reviewer 3

This work contributes to advances in EV component development.

Reviewer 4

The project is targeted at lightweight for EVs.

Reviewer 5

The project supports the lightweighting goal as brakes are a very heavy vehicle sub-system.

Reviewer 6

The new application for EVs is highly relevant to the subprogram objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

Team is well suited to performing the work proposed at an advanced level. The funding is moderate but well positioned within the propulsion materials thrust area.

Reviewer 2

The resources are sufficient to carry out the tasks proposed.

Reviewer 3

The resources appear sufficient.

Reviewer 4

Resources were sufficient for the tasks outlined.

Reviewer 4

Resources available to the project were not discussed.

Reviewer 4

Resources were sufficient but more focus is needed to align with and understand the needs of brakes for the EV drive cycle.

Presentation Number: mat160
Presentation Title: Cost Effective Lightweight Alloys for Electric Vehicle Propulsion: Hybrid Dispersion Strengthened AL Matrix Composites for Higher Efficiency Electric Vehicle (EV) Powertrains
Principal Investigator: Mert Efe, Pacific Northwest National Laboratory

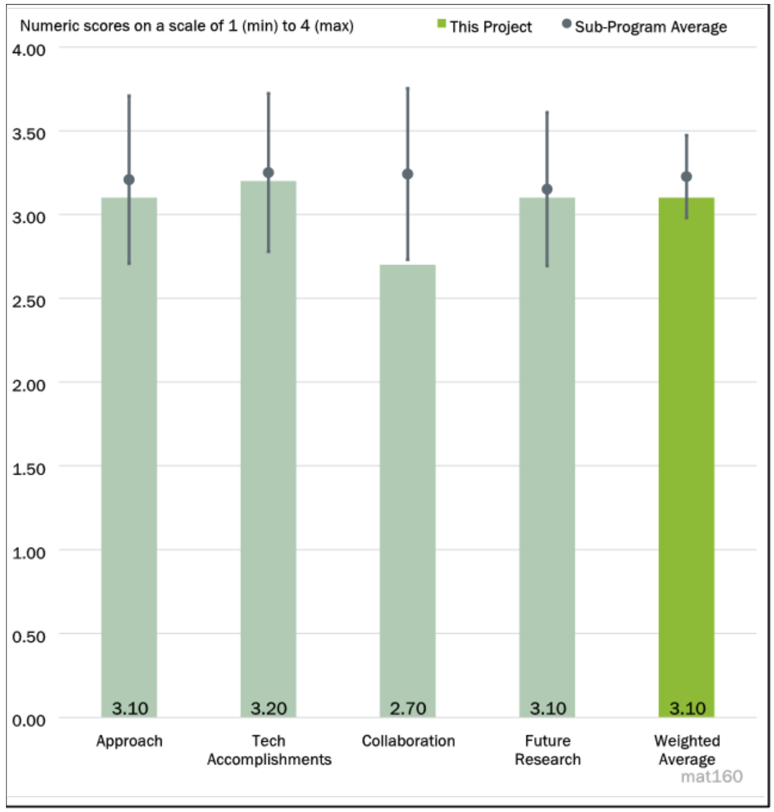

Figure 5-7 - Presentation Number: mat160 Presentation Title: Cost Effective Lightweight Alloys for Electric Vehicle Propulsion: Hybrid Dispersion Strengthened AL Matrix Composites for Higher Efficiency Electric Vehicle (EV) Powertrains Principal Investigator: Mert Efe, Pacific Northwest National Laboratory

Presenter

Mert Efe, PNNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: ***Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?***

Reviewer 1

Overall, the in-situ reaction interesting approach looks good and has a lot of potential. A lot of time was spent on the understanding of demand applications, but this may have been excessive.

Reviewer 2

The use of Al metal matrix composites (MMCs) for gears is very exciting and has direct relevance in EV development. A lot of focus is on technologies already deployed such as Al rotors. Additional funding would offer many options to designers as they look to decrease spinning mass, which has an increased effect on range over normal vehicle loads.

Reviewer 3

Brake rotor application typical operating targets is benchmarked and the Al MMCs appear to show a reasonable match for the application. Strength targets for Al gears are 2-3x below current carburized steel levels and a breakthrough in strength appears necessary to make Al gears viable.

Reviewer 4

The reviewer encouraged the authors to list all the key requirements for brakes and gears and state why their material potentially addresses these requirements. Collaboration with component suppliers should be considered important (addressed later under collaboration).

Reviewer 5

The project is in early stages and the technical barriers are yet to be overcome. Some of the barriers include formation of titanium diboride (TiB_2) particles by in-situ reactions, distribution of particles of specific size ranges at various location of the parts, absence or close to no porosity, matrix softening, and mechanical performance, etc. The challenges are quite daunting for a two-year project.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The novel work in gears is stellar, and the opportunity to create TiB_2 in-situ is very interesting. Development of an isotherm associated with the TiB_2 formation that could be monitored during solidification as a quality control was suggested. Stir casting is interesting, but this process has never been successfully commercialized after a lot of research over many years. It would be great if this project could overcome that barrier that would spin-off a lot of recent opportunities for the technology.

Reviewer 2

Matrix alloy, processing method, mold designed to minimize porosity, A356 solidification, and wear rate experiments completed demonstrate test method viability. 7075 test samples made show various levels of mixing and some opportunity areas.

Reviewer 3

In the first three months after the project start in October 2021, the stir caster was shown to perform adequately with a 356 alloy. Although the scope of the work is to use in situ reactions to introduce TiB_2 in the composites, the reported results appear to be on the composite where TiB_2 particles were incorporated in the alloy 356 using a friction stir process.

Reviewer 4

Progress seems reasonable and processing approaches are innovative. The reviewer suggested characterization of any residual fluoride content as it may have an impact on the behavior. Fatigue property is likely to be a potential problem and yet to be tested, and so need to be prioritized in the near future for this new project.

Reviewer 5

Only the casting and tribology progress is shown in the presentation. Elevated temperature and bending fatigue testing approach is not shown, even if not done.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

Collaborations expected to be established with ORNL for brake testing and also with industry for stir casting.

Reviewer 2

Good research and having team be in a single location at PNNL makes this easier, and they clearly have capitalized on that.

Reviewer 3

No listed partners outside PNNL are working on this project, but the principal investigator (PI) is reaching out to gear and brake experts in industry. It would be useful for experts be a little more aligned to brake validation requirements and standards currently in place. Benchmarking and designing for typical operating temperature conditions may not suffice for abusive conditions mandated in OEM validation testing.

Reviewer 4

Only ongoing collaboration appears to be with ORNL. There is no collaboration with component manufacturers who have the requirements for the parts as well as testing capability. This is sorely needed to make progress in a component that has evolved and matured over time, particularly for very demanding applications of gears and brakes. Stiffness, for example, is a key requirement for gears and cannot be solved with larger gears as there is no space. The reviewer suggested discussion with the project MAT159.

Reviewer 5

There does not seem to be much ongoing project collaboration. Nothing seems to be currently going on as only a company discussion and development of a collaboration with ORNL is underway.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

Proposed future work seems reasonable.

Reviewer 2

Squeeze casting proposal is nice, should be a logical next step to increase density. The tensile testing of the friction consolidation samples will also help define next steps as it shows the direct influence of that process.

Reviewer 3

While gear applications appear to be a ‘stretch goal’ for the 7075 composite, it is worthwhile to see what else can be done in this space by evaluating other matrix alloys and coating options.

Reviewer 4

The project needs to address the key considerations as it appears too casting focused.

Reviewer 5

Issues related to key items such as controlling the particle distributions, porosity, and matrix softening in braking applications need to be given more thoughts and a detailed technical plan needs to be worked on.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said it is a great work. Lower mass in any rotating components increases acceleration at constant power and decreases losses during deceleration including regeneration. This is a very important space to mine in the work to increase EV range and increase the number of consumers that would be willing to purchase an EV by overcoming range anxiety.

Reviewer 2

Reducing rotating mass of vehicles by using Al brake rotors has good merits for fuel economy/range extension. Similarly reducing mass of gears will provide benefits, but probably less so than the brake rotors due to lower rotating inertia.

Reviewer 3

Lightweighting is a key imperative in this project.

Reviewer 4

Use of MMCs can contribute towards lightweighting of EVs by obviating the use of steel and cast iron parts. This will be beneficial in extending the range for the EVs. Furthermore, lighweighting can also lead to smaller size batteries for the EVs. The project is well aligned with the goals of VTO's Materials Program.

Reviewer 5

The proposed work is very relevant to the program goals for EVs.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

Resources seem to be in line with accomplishments and opportunities.

Reviewer 2

Resources appear to be sufficient.

Reviewer 3

Sufficient resources from PNNL as listed but unclear about the other resources.

Reviewer 4

During the project duration, the team will be looking for external collaboration with industry in the area of squeeze casting.

Reviewer 5

The resources were not evaluated as they were not addressed in the presentation.

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 four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

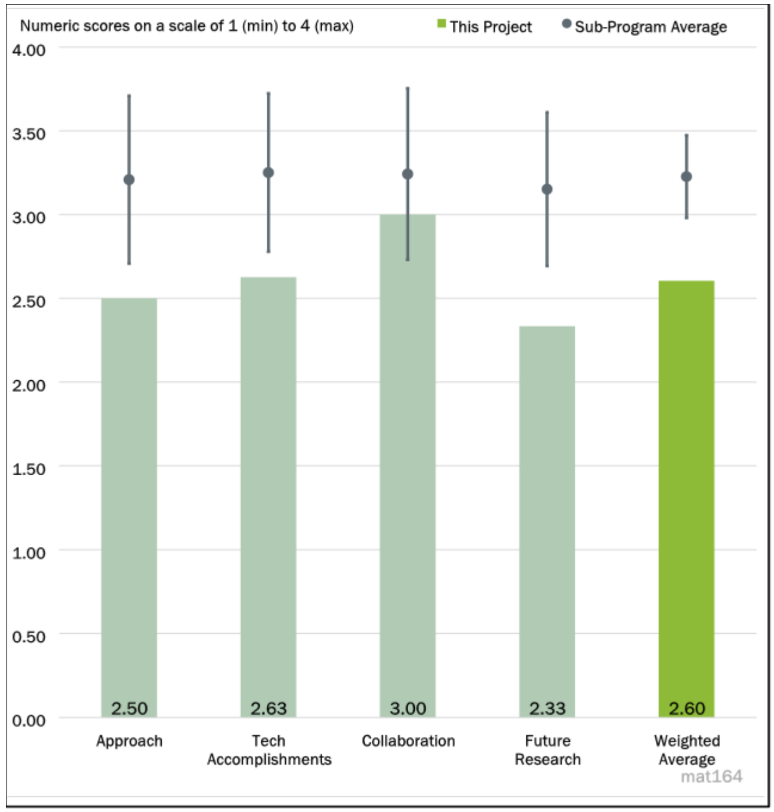

Figure 5-8 - Presentation Number: mat164 Presentation Title: Multiscale Development and Validation of the Stainless Steel Alloy Corrosion (SStAC) Tool for High-Temperature Engine Materials Principal Investigator: Michael Tonks, University of Florida

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The original multi-scale modeling approach was promising. Incorporating phase field modeling with atomic scale simulations with lab experiments is logical. The evaluation of oxygen mobility in varying oxide phases is of value, as is the study of the growth order of the oxides with varying alloy composition and chromium (Cr) and manganese (Mn) depletion in stainless steels.

One of the main objectives of the project to quantify the impact of microstructure and alloy composition on valve steel corrosion, which were valuable and relevant goals. However, at 95% of project completion (4- year effort), the impact of the following key factors is still not incorporated in the presented results: alloy microstructure; water vapor effects (since the combustion environment is being modeled); and engine validation (which has begun). It seems very unlikely that if the first two have not yet been investigated and incorporated at 95% completion of the project, they will not be achieved in the final 5% stage of the effort as those two factors are among the most complex endeavors described. It seems the approach to the proposed work did not adequately prioritize the importance of simulating microstructure and water vapor in prior years. The approach does not account for one of the most essential elements of oxidation behavior of time prediction to oxide spallation at the targeted temperature and atmosphere (water vapor and dry environment). It is oxide spallation that often defines the initiation of accelerated oxidation attack and component degradation in most alloys although the Cr depletion is being modeled.

Reviewer 2

The model appears to be focused on understanding and quantifying the migration barrier for vacancy-based diffusion but unclear what will the tool allow the industry to accomplish. The role of Ni is not captured and how the microstructure of a single austenite phase will be modeled is not clear. It was unclear whether the oxidation layer growth is the key to engine valve performance which has been around for a while else the audience assumes that other factors are not considered. A lot of supplier data on engine valve materials and their behavior should also be available in the open literature. The model should be applied to those materials to demonstrate the robustness of the model. The project does not identify what it is looking for in terms of engine operation: lighter valves, smaller valves, higher temperature valves, or lower cost valves.

Reviewer 3

The project aims to develop Stainless Steel Alloy Corrosion (SStAC) tool to predict corrosion performance of stainless steel at high temperature. The second objective is to "Quantify the impact of microstructure and alloy composition on valve steel corrosion using laboratory and engine experiments and mesoscale modeling and simulation." The project team has developed a tool, but the impact of microstructure and composition are not well addressed. The tasks designed are not enough to address them. The characterization of oxide film shows only scanning electron microscopy (SEM) energy dispersive X-Ray analysis (EDAX) map but lack of phase and thickness information.

Reviewer 4

The current project approach requires too many parameters that are not readily available and thus experimental calibration is needed to perform any simulations. It is understandable that the first-principal type of prediction is not yet available due to the complexity of the field. It appears that the boundary condition of this approach is very narrow, i.e., the specific type of alloy, temperature, and operating conditions.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The project team developed the tool that shows the same trend as the experiment, but it does not match the experimental result quantitatively with the goal of within 10% error. It is probably understandable since the tool has not considered microstructure.

Reviewer 2

The project appears to have successfully predicted oxidation rate and Cr/Mn depletion at one temperature including the model prediction of its depletion for specific alloy compositions. It would be good to see a new model capability that delivered more than prediction of oxide mass gain and Cr/Mn depletion in dry carbon dioxide (CO_2) after 4 years of effort and almost $1.5 million invested.

At 95% of the project completion ($1.5 million over 4 years), the impact of the following key factors remain to be incorporated in the results under review: a) alloy microstructure, b) alloy composition, c) the quantification of the impact of microstructure and alloy composition on valve steel corrosion (main project objective) d) water vapor effects (since the combustion environment is being modeled), and e) engine validation (which seems to have begun). As (a), (b), and (d) factors have not yet been investigated and incorporated at 95% completion of this project, it is unlikely they will be at the final 5% of the effort—as at least two of those factors are among the most complex endeavors described. It is surprising to note that after 4 years of effort, the new oxidation tool predicts only oxidation mass gain and is unable to predict essential outcomes such as: a) time to spallation of the protective oxide layer, preferably at various temperatures, b) time to spallation of the protective oxide layer at specific temperatures for comparative alloy compositions, and c) the effect(s) of water vapor on oxidation kinetics and time to oxide spallation on various alloy compositions at various temperatures. These are the essential questions necessary to guide alloy design and/or selection for specific applications. The modeling of the valve shown in Slide 12 would require simulation of varying temperatures over the length of the valve, since even peak temperature varies with location and combustion conditions over such exhaust components. On the positive side the model does predict Cr and Mn depletion for specific alloy compositions.

Reviewer 3

The comparison of model data for oxidation in dry CO_2 has been done at the project end, where the effect is minor. The model calculates weight gain, while all the preceding data is thickness. It is difficult to do the translation including curve shape even at the bottom of Figure 6 and compare the two curves.) should use Similar colored symbols for the right and left plots showing oxide character should be in used in Figure 7 (bottom right). Also, the alloy and oxide are reversed between the two figures; alloy and oxide should be in similar Left/Right placement to allow easy comparison. Finally, Figure 13 shows comparison of model and data. It is unclear about the benefits of a 10% error prediction shown in comparison of model and data in Figure 13, especially when the correlation is for dry CO_2 where not much is happening.

Reviewer 4

The amount of work performed within the project is good. However, the direction and the actual work done, particularly for model/simulation tasks, are rather questionable. For example, the discrete Fourier transform (DFT) calculations of activation energy for metal cations in the oxides can be regarded as a very nice fundamental and low-level study, but it is not explained how such information has been used/connected to the different simulations.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

There seems to be good collaboration with University of Wisconsin, Tenneco, and Idaho National Laboratory (INL), although at 95% of project completion stage the macroscale tool development and validation against Tenneco engine testing data are yet to be completed. As the engine testing is in progress has been mentioned during the presentation, so those outcomes can be anticipated. The monthly project meetings are a good strategy. A substantial quantity of essential effort is occurring in the last 5% of the project, so it is very difficult to assess the probability of successful completion of these key activities.

Reviewer 2

The project team consists of national lab, universities, and industry partners. The effort on material characterization has some room for improvements.

Reviewer 3

The reviewer recommended the industrial collaborator to provide a sense check based on years of experience with valve materials. The reviewer questioned whether the observed literature results on the replacement of nickel (Ni) with Mn is similar in actual engine tests.

Reviewer 4

The collaboration and coordination among the project team members look good.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

If there is a follow up project, the reviewer said consider the impact of microstructure, as indicated in the previous review.

Reviewer 2

The amount and relevance of remaining effort reported is remarkable at this 95% project completion stage. The key objectives of the effort such as water vapor as well as microstructure and alloy composition remain to be considered. Tool validation for various alloys and engine conditions remain. The remaining effort described on Slide 16 seems to far exceed the remaining time and budget for the project, but it is possible that significant progress has been made. It is encouraging to note that engine validation has begun.

Reviewer 3

The project shows 95% complete yet the key items of introducing water vapor, alloy composition, and microstructure are yet to be addressed. It is unclear whether all the data has been collected as they were not presented.

Reviewer 4

The effect of microstructural evolution is important; however, it is not clear how it will be incorporated in the future research.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The project supports the VTO objectives on Materials.

Reviewer 2

The project is relevant and supports overall VTO objectives.

Reviewer 3

The product benefit of this work relative to the DOE goals such as cleaner engine, etc. need to be stated.

Reviewer 4

The research topic is very well-aligned with the VTO program objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The resources provided were sufficient.

Reviewer 2

The team is well resourced.

Reviewer 3

The resource allocated may neither be able to consider the impact of microstructure and composition nor validate the tool with other alloys.

Reviewer 4

$1.5 million for a 3-year project for an academic institute is a very large award, and the project outcome is only valid for a specific class of alloy at a specific temperature/environment.

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

Presenter

Merlin Theodore, ORNL

Reviewer Sample Size

A total of one reviewer evaluated this project.

Project Relevance and Resources

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

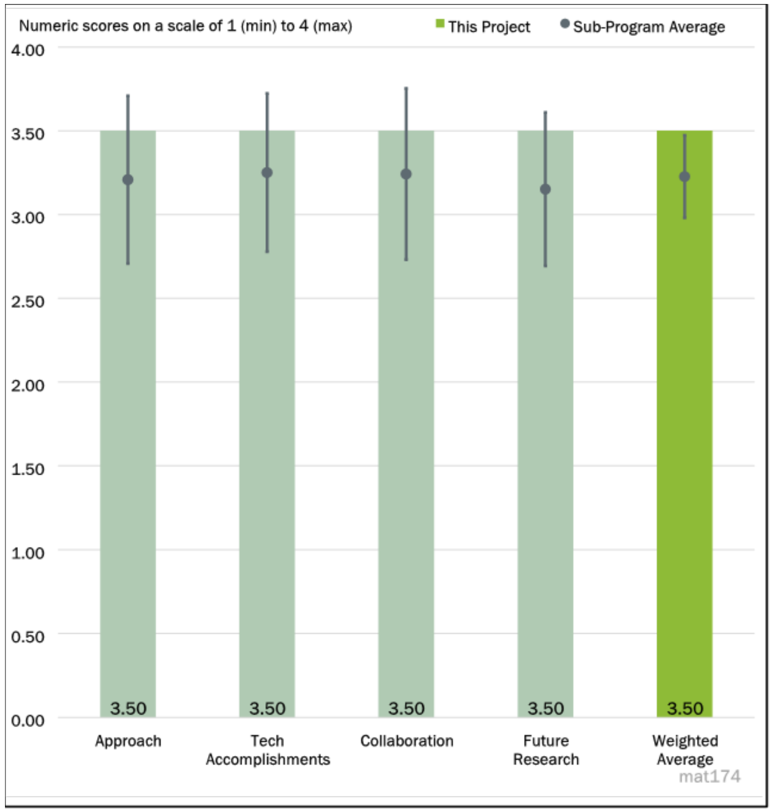

Figure 5-9 - Presentation Number: mat174 Presentation Title: Carbon-Fiber Technology Facility (CFTF) Principal Investigator: Merlin Theodore, Oak Ridge National Laboratory

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The Carbon Fiber Technology Facility (CFTF) is the only CF R&D facility which is important for critical material scaling. The project is well positioned to address the technical barriers for the material scaling. The project timeline is reasonable, and the project is on track.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The CFTF extends polyacrylonitrile (PAN) precursor to textile PAN, melt blown pitch, and nylon precursors. The project is on track and has met the milestones as planned. The technical challenges have been well identified. The accomplishments on scaling textile PAN, melt blown pitch, and nylon precursors have been demonstrated.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The CFTF is the central facility for the scaling of CFs. It provides a platform for collaboration with academy and industry, and they have been going well.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The future research plan has been well proposed containing reasonable targets with the thoughtful risk mitigation plan. The project is anticipated to achieve its targets.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

Carbon fiber is the critical material to reduce vehicle weight and carbon emissions. Low-cost lightweight CF is anticipated to reduce batteries and extend vehicle range for EVs. The CFTF serves as a bridge for scaling up and technology transfer.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The CFTF is well equipped with state-of-the-art resources and an easier access to the characterization facilities and expertise in ORNL.

Presentation Number: mat195
Presentation Title: Industrialization of Carbon Fiber Composite Wheels for Automobiles and Trucks
Principal Investigator: Brian Knouff, Oak Ridge National Laboratory

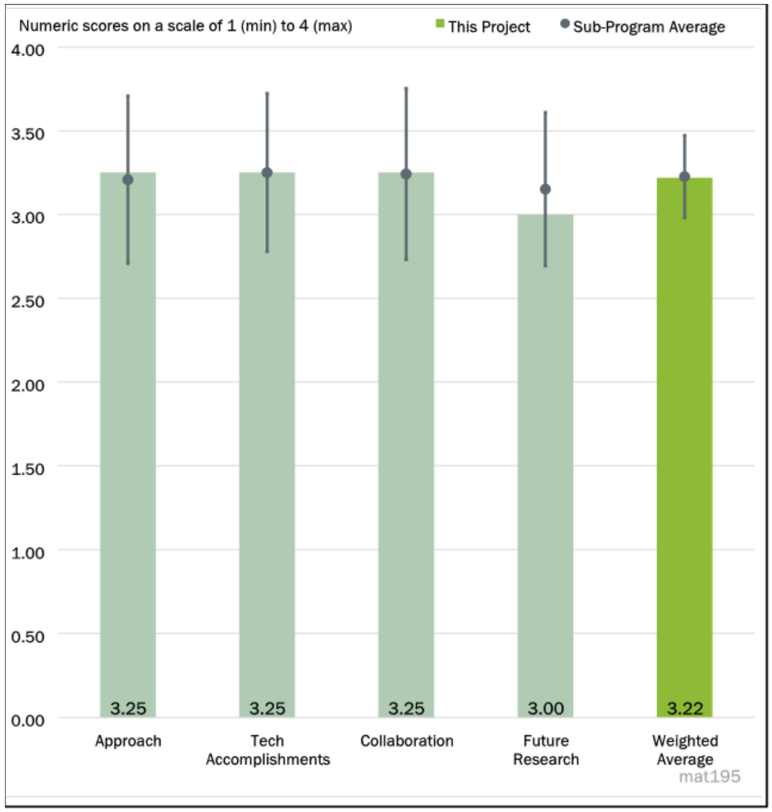

Figure 5-10 - Presentation Number: mat195 Presentation Title: Industrialization of Carbon Fiber Composite Wheels for Automobiles and Trucks Principal Investigator: Brian Knouff, Oak Ridge National Laboratory

Presenter

Brian Knouff, ORNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The effort on the project has been commendable with a focus on the basic material testing and design of wheels. The effort would be complete with the consideration more basic material selection as well as the molding processes.

Reviewer 2

The tailored fiber placement (TFP) and AM technologies are being used to maximize the value of composites. Physical testing of the wheels for the validation of the virtual tools and demonstration on the value of this new development over baseline is yet to be planned.

Reviewer 3

A methodological project approach was used. The team faced many barriers during COVID-19 that impacted their schedule on fabrications that needed to be completed to meet milestones. The team modified their approach and focused more on the modeling aspect that was to be completed in year 2. The team benefited from the change learned from the design approach. Wheels and plaques for testing were then fabricated using the design change. The final goal of weight reduction in wheels using composites with out of autoclave processing has been met by the project.

Reviewer 4

The project goals are clear, and the manufacture of functional prototypes shows strong progress. A cost/performance comparison of other technologies being commercialized would be helpful.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The participants have done commendable work in making progress according to plan despite of the slowdown caused by the pandemic.

Reviewer 2

The main progress has been on coupon testing and how this would facilitate in the baseline wheel design improvements was not discussed. The discussion on details of the completion of the fabrication and testing of new wheels shown on Slide 4 has been unavailable.

Reviewer 3

The team is on the 80% project completion target. The team was able to get back on track of the plan with all the challenges and be a successful project end. The test data presented indicated lots of progress. It is difficult to assess whether the material property tests were exceeded or are 90% of target without any metrics. The remaining environmental tests are yet to be completed.

Reviewer 4

The manufacturing approach is good with functional prototypes being manufactured. There is limited information of the materials being utilized from a fiber and resin perspective.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The two collaborators worked great together with each other relying on their strengths. The success and progress in the project through difficult times were evident by the excellent results presented and the completion of the project to date.

Reviewer 2

There is significant cost share between the partners.

Reviewer 3

The reviewer was pleased with evaluation of the AM tooling. The reviewer encouraged more interactions with the ORNL expertise to lead to the design improvement over baseline wheels by ESE Carbon Company.

Reviewer 4

The work would have been more complete and have more relevance if it included and stated the types of fiber that was (were) used and factors affecting the molding cycle time. A third or a fourth project participant such as a fiber manufacturer or an OEM may have been useful as these factors will affect the cost viability of the product.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

Project has a reasonable plan.

Reviewer 2

This is an extremely relevant work. The understanding of cost versus performance consideration in future work may be important. A deeper dive into the manufacturing process (e.g., TFP and molding) with the use of AI – ML techniques, and use of blended or hybrid fibers driven by an understanding of the stress distributions may be useful to further optimize the product. One of the questions raised on paramount appearance factor for automotive needs to be included into the objectives.

Reviewer 3

The project is nearly complete with environmental and fatigue studies remaining. The last major item to complete is the AM tooling study that would improve the tooling cost by 50%. This would be a significant impact on the wheel costs and achieve the weight savings into vehicles. Designs were also shown on how to improve the thermal management in the tooling.

Reviewer 4

Future research plans could be better stated. It is not clear whether the current materials meet all target mechanical properties and the thermal performance with all testing is being performed at room temperature.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

Development of a lightweight automotive structures is very relevant today to achieve an overall reduction of carbon emissions. The project team should consider the challenges of a difficult composite wheel task. A promising path has been considered but more work will be necessary to take this effort into the mainstream.

Reviewer 2

The reviewer noted that CF wheels provide vehicle lightweighting potential.

Reviewer 3

The project supports the materials program by demonstrating a 40% weight reduction over Al wheels. It also has elements on how to reduce manufacturing cost by demonstrating out of autoclave process over traditional high performance aerospace autoclave processes. Lastly, using AM to further reduce tooling cost by 50% due to complex thermal management channels that are difficult and expensive in machining.

Reviewer 4

The important component of lightweight reduces unsprang mass, rotational inertia, and total wheel weight.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said resources are sufficient.

Reviewer 2

The reviewer remarked the project team has done a wonderful job for this tough task, based on the program on a process, i.e., TFP that came from the textile industry. An excellent demonstration on how one can learn from adjacent technologies in the effort to use continuous fibers effectively for weight reduction. More effort and resources should be directed into this and similar projects. The reviewer suggested additional resources for a complete understanding and molding process improvements, and then taking the molded wheels through the rigors of OEM evaluations for increasing the worth of this effort.

Reviewer 3

The team achieved all milestones in the project plan. All milestones have been except for one for TFP parametric study, which was removed due to COVID-19 and the inability to get it done are the legitimate reasons for the one milestone exception.

Reviewer 4

There is significant cost share between the partners.

Presentation Number: mat196
Presentation Title: High Temperature Carbon Fiber Carbonization via Electromagnetic Power
Principal Investigator: Felix Paulauskas, Oak Ridge National Laboratory

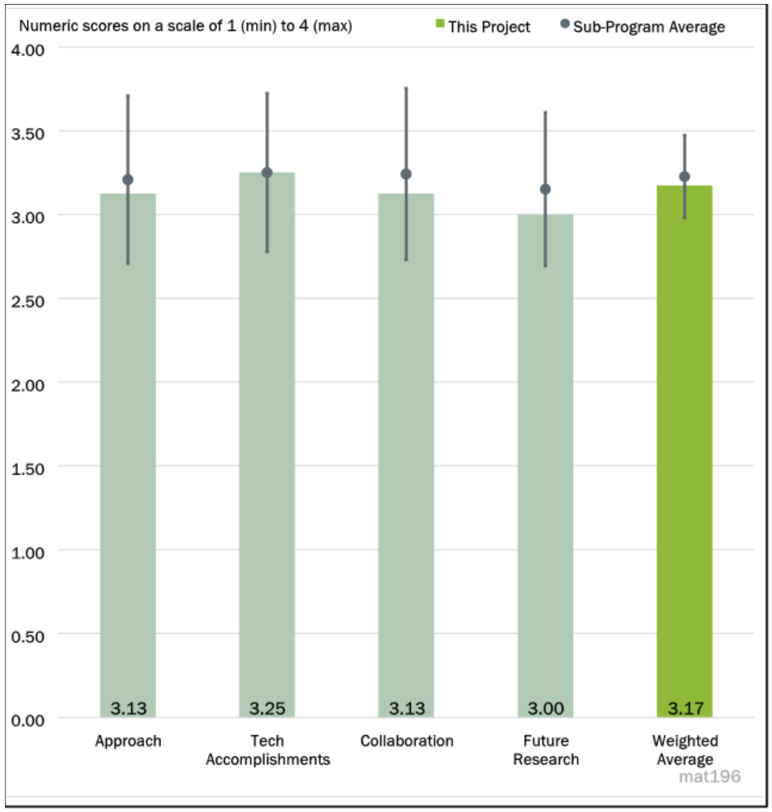

Figure 5-11 - Presentation Number: mat196 Presentation Title: High Temperature Carbon Fiber Carbonization via Electromagnetic Power Principal Investigator: Felix Paulauskas, Oak Ridge National Laboratory

Presenter

Felix Paulauskas, ORNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said the project has a reasonable approach on using dielectric heating to reduce the carbonization cost. The reviewer suggested a cost modeling result directly comparing the proposed and conventional high temperature carbonization (HTC) processes.

Reviewer 2

The reviewer said parametric tests need to be well calibrated in order to achieve the desired result of obtaining optimum conditions to fabricate the carbon composite. Enough time to reach the end of the tests should be ensured to correct or understand the desired test time. It is presumed that a cost analysis will be part of this work, as nothing is mentioned in the future work section about it.

Reviewer 3

While the approach is innovative, perhaps the focus of the efforts could be narrowed to improve the overall opportunity for success and being able to fine-tune the resulting fiber performance in terms of both properties and consistency. For example, the cited "positioning challenges" could be the only source of manufacturing variability. Data reporting with statistics is generally a good approach and the project could consider stepping back and focus on 1 x 100k first the evaluate the fiber performance variability.

Reviewer 4

The project team is working toward developing a CF based on high temperature carbonization in which the heating is enabled through dielectric heating. The goal is to achieve faster and more efficient conversion than conventional process and scale to capacity up to one annual metric ton by end of the project. The tensile strength ranges from 260-380 ksi and tensile modulus of 27.7-29.5 msi based on location within the furnace presented on Slide 9 seem to be consistent with the milestones presented on Slide 4. It was somewhat unclear where the current work began to evaluate significant 'current' contribution(s) as several of the frontend slides were repeats from prior years. Some timeline gaps perhaps due to COVID-19 or other circumstances were not clear to the reviewer.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer remarked good progress in general.

Reviewer 2

A bit of data remains to be collected as part of the parametric studies as alluded by PI alluded for a better understanding of the impact of input parameters on the physical properties and morphology of the CF.

Reviewer 3

The project appears to be progressing satisfactorily thus far by meeting the milestones. Significant challenges remain to be addressed in order to meet the stated goals and objectives. It is not clear if these challenges can be successfully resolved within the remaining performance period.

Reviewer 4

The work is technically strong and interesting. The science behind the project is excellent and the reviewer suggested the team consider the value proposition for it to make a big market impact after the project is completed. This was not very clear at this time. It is unclear about the project status on the metrics for tensile strength and tensile modulus of their fiber under development in comparison to: (a) the ORNL CFTF textile grade fiber which has exceeded 400 ksi and 35 ksi, (b) the Deakan fiber, which is also based on the low-cost premise, or (c) Zoltek PANEX which is now marketed at more than $5/lb. It is unknow what specific space does this project attempt to fill amongst its competition. The reviewer suggested a fair side by side comparison of this fiber to various ones identified here at the next review. This could also include comparison of the energy metrics to determine whether the current fiber is lower in energy consumption and reasons for it.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The collaboration between ORNL and 4X Technologies is logical and the developmental work done at ORNL has a pathway to scale up at 4X.

Reviewer 2

Roles of the partners are clearly defined, and work is well coordinated.

Reviewer 3

Collaboration between geographically close in proximity ORNL and 4X Technologies seems has facilitated a good and close working relationship. It is unclear about specific contributions 4X has made and planned in the future.

Reviewer 4

The PI adequately addresses the role of collaborator 4XTechnologies. However, one of the project partners, i.e., Pol Grappe, is mentioned on the title slide but not on the overview slide. If they are indeed partners, their role and contributions are not immediately evident. Further, it may be beneficial to the PI/team to have the CF products developed also tested by a suitable independent partner.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer inquired whether the team has considered a comparison of the properties of the fibers processed via the proposed and conventional HTC processes.

Reviewer 2

Cost analyses is suggested as the future research area.

Reviewer 3

The PI has articulated the remaining work and challenges for the remaining duration of the performance period. Perhaps, as a part of the remaining future work, the quantification of the expected cost savings, estimated with a reasonable fidelity may help showcase the success of the technical approach.

Reviewer 4

The reviewer cited prior comments, which are also applicable in this case. The in-depth project plan is unclear as the remaining challenges and barriers and future work were barely bulletized in the presentation. For it was not clear how the impressive 700 ksi would be attained. Although it was not a programmatic milestone, but the rationale behind it was not clear. Slides 17 and 18 could have used additional elaborations as it was not easy to assess based on limited information.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The project is relevant to DOE/VTO as low-cost CF for future of the U.S. economy is a DOE and Presidential initiative.

Reviewer 2

Reducing CF cost is critical to expand the application of CF composites.

Reviewer 3

This project will help to reduce the cost of CF and hence CF composites, which will affect energy efficiency of mobility systems.

Reviewer 4

If the goals of this project are realized as articulated, the technology developed could have the potential for reduced energy consumption (hence, embodied energy), and afford a modest cost reduction in the manufacture of CFs. It would thereby serve to support the VTO program objectives for Materials.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

Sufficient resources are available to this project.

Reviewer 2

The resources seem adequate.

Reviewer 3

The project is well resourced, and sufficient to achieve the stated but some narrowly focused milestones in a timely fashion. Any supply chain disruptions at this stage may challenge the project.

Reviewer 4

The resources between ORNL and 4X are sufficient. ORNL line upgrade plan was mentioned but it was not clear how uniform heating of the fiber to obtain narrow properties bound would be ensured. The existing properties are highly dependent on the location.

Presentation Number: mat197
Presentation Title: Multi-Functional Smart Structures for Smart Vehicles
Principal Investigator: Patrick Blanchard, Ford Motor Company

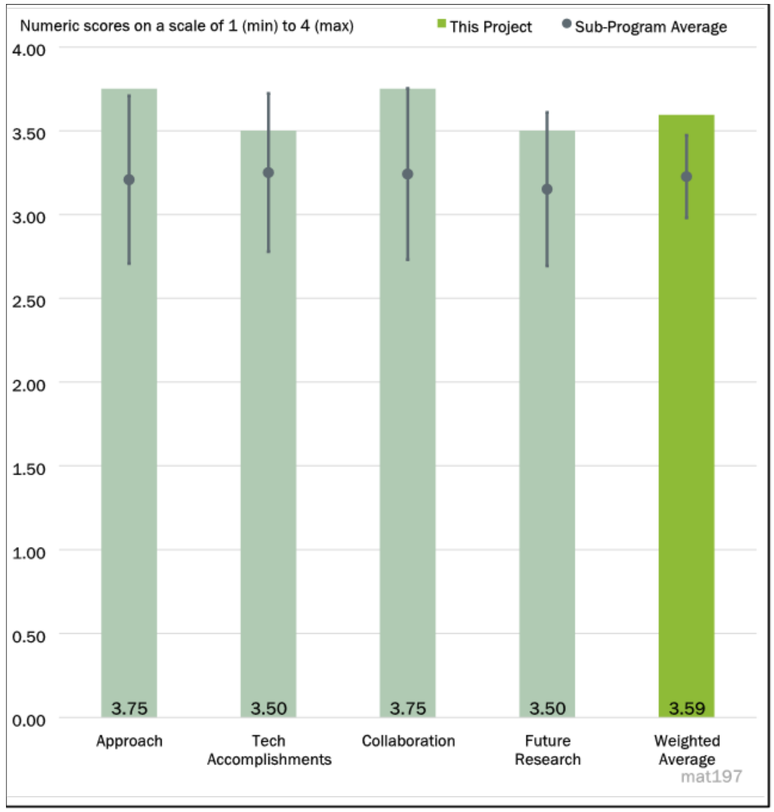

Figure 5-12 - Presentation Number: mat197 Presentation Title: Multi-Functional Smart Structures for Smart Vehicles Principal Investigator: Patrick Blanchard, Ford Motor Company

Presenter

Patrick Blanchard, Ford Motor Company

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The project is well designed and executed very well. The ongoing work integrates several technologies that were generally isolated in prior applications. Using a cross-arm as the member of interest, the team is exploring all-in-one recycled materials, embedded electronics, process innovations for hollow sections, thermally and electrically conductive polymers, hybrid continuous-discontinuous, and AI. The vision and efforts of the project team is well aligned with the direction of the mobility feature. The timeline is managed well and despite COVID-19 constraint the team seems to have advanced and is on track.

Reviewer 2

The project is well designed. Some technical barriers such as water-assisted injection molding, composite recycling, and sensor development, etc. have been addressed. It is not clear whether it will be easier to integrate the sensing devices at a later (separate) stage rather than in-situ during the electronics integration stage, which might overcome the fabrication incompatibility issue.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

It is a well-managed project, and the technical accomplishments are on track with no outstanding tasks. The team has completed the cross-beam concept development with extensive ribbed structure. A cost metric is also included to illustrate that the cost metric is achievable. Mass savings of greater than 40% has been demonstrated at cost of $1.93/lb which is impressive given the proposal target is $3/lb. The team has considered a range of material streams and the property (performance)-process-cost relationships are currently ongoing. Water injection molding and associated tooling for hollow shapes has been an excellent innovation with potential to save energy. Concepts of tape placement and sensor integration have been advanced including AM attachments and hard points are being integrated. AM tooling and recycled materials are also being considered in the study.

Reviewer 2

The research team utilizes a convergent approach. Many sub-components have been developed and their properties/performance have been demonstrated. The following project period would focus on integrating them together to demonstrate a working prototype.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The team has complementary expertise. The specific contribution from each team member is very clear.

Reviewer 2

The project has demonstrated a case of collaboration. The task distribution is clear, and the project management ensures that all partners deliver in a timely fashion. There is no duplication or bias of the work, and the team is well organized.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The PI has laid out clear goals for future research. Given the current progress, the future work will very likely achieve its targets based on the current progress made.

Reviewer 2

The proposed future directions on Slide 20 are appropriate. It is not clear about the build prototype tooling to manufacture cross car beams for testing and validation stage although materials and processing optimization will continue. Full scale injection molding including the ability to fixture inserts and continuous fiber into the injection mold and retain them through the injection process will be demonstrated. It was not clear about the material for the prototype tool, i.e., Al, AM, or other and for injection molding. The overmolding tool feature is a good plan and some more details on this would be helpful. It would be good to follow up in the coming periods.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

As stated in Question 1, the proposal integrates numerous emerging trends in future of mobility. The work aligns well with the VTO objectives.

Reviewer 2

The goal of this project is to develop a new class of multifunctional composite materials and processing technologies for producing lightweight recyclable structures with fully integrated sensing devices, which is highly desired for future vehicle manufacturing.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said Ford, ORNL, Purdue, MSU, and Yanfeng have more than adequate capabilities to address the proposed work.

Reviewer 2

The research team has all the necessary resources for this project.

Presentation Number: mat198
Presentation Title: Development of Tailored Fiber Placement, Multi-Functional, High-Performance Composite Material Systems for High Volume Manufacture of Structural Battery Enclosure
Principal Investigator: Venkat Aitharaju, General Motors Company

Presenter

Venkat Aitharaju, General Motors Company

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

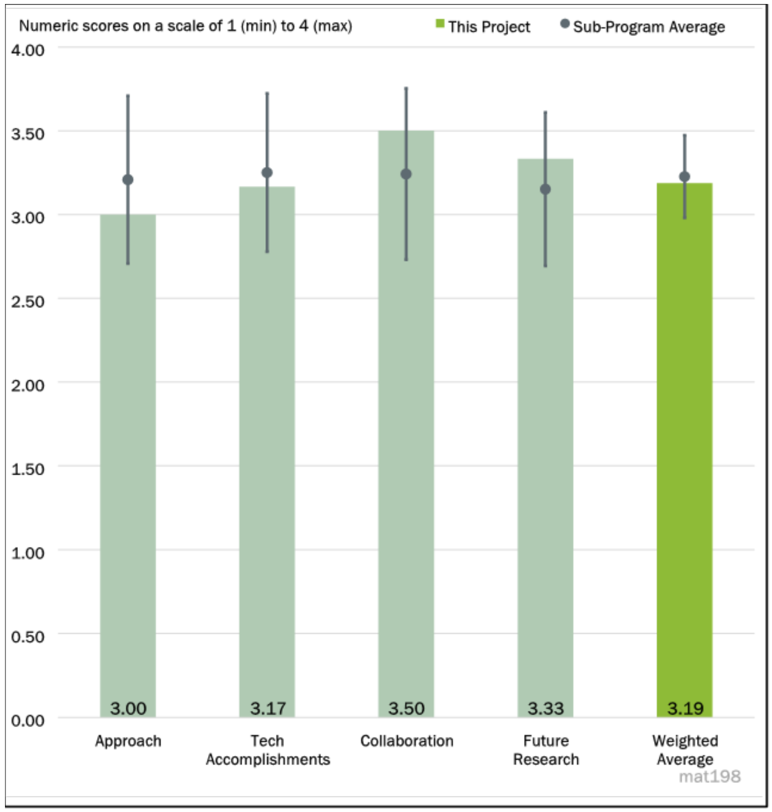

Figure 5-13 - Presentation Number: mat198 Presentation Title: Development of Tailored Fiber Placement, Multi-Functional, High-Performance Composite Material Systems for High Volume Manufacture of Structural Battery Enclosure Principal Investigator: Venkat Aitharaju, General Motors Company

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The technical barriers have been identified and addressed. The project is well- designed and -planned. The novel approach of creating a hybrid composite with glass and CFs was not clear. A more novel approach to meeting the technical barriers should have been proposed based on the large available DOE project budget.

Reviewer 2

The project timeline is reasonable, and it has addressed many critical barriers to meeting the minimum requirements. The focus on hybrid fibers (carbon/glass) has been excellent and detailed work has been carried out. There was no detailed work on fire retardance, and electromagnetic compatibility (EMC) performance mentioned in various slides, but it may be planned for the next fiscal year. Some areas such as crashworthiness and thermal management requirements for multi-functional battery enclosures still could have been included in the approach.

Reviewer 3

There has been delay in the project due to pandemic, and so some technical challenges remain to be addressed. For example, the CF tow was designed to functionalize as the strain sensor, but its integration effect on the final composite mechanical properties and the final product cost remains unknown.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer remarked the work done is excellent and in line with the proposed work within over a year of the project start. The technical progress is targeting most of the critical barriers with a few exceptions such as incorporating EMC and fire-retardance properties at the design phase itself as these functionalities are hard to incorporate later.

Reviewer 2

The research team completed some tasks, such as composite preparation, characterization, sensor design, and predictive model development in spite of the project progress slowdown caused by the pandemic.

Reviewer 3

The team made good progress on achieving the milestones this past year. The milestones consisted of a variety of sensor development and additional functional properties that were integrated into the composite. The reviewer suggested showing in future AMR presentations how the progress was measured against the listed criteria towards meeting the milestones. The results should accompany the criteria on the slide for that research task to measure success of the task quantitatively. It would be good to include the data used to quantify the fire-retardant capabilities which was mentioned as the most important functional properties for the automotive industry. However, no data was presented that quantified the fire-retardant capabilities. It was not clear how good of a flame-retardant is the matrix as the fibers are inherently flame-retardant.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The research team has complementary expertise.

Reviewer 2

The project team consists of an excellent team of partners and collaborators. It would be good to note which partner/collaborator is working on which part of the project in in future AMR presentations. The project role of the partner Coats was described, but not for the rest of the partners/collaborators.

Reviewer 3

The number of participants and their expertise were mentioned, but a clear and specific contribution from each partner for this project was not covered. Therefore, it was difficult to understand the specific contributions requirement from the other partners in the future.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The remaining challenges and barriers have been identified and there is a clear plan to effectively overcome those barriers within the future proposed research. The future research directions seem reasonable and attainable in the remaining time of the project based on the prior accomplishments. It would be good to show what electrical system would need to be added to the battery enclosure to utilize the self-sensing attribute of the enclosure for the last bulleted future milestone of the battery enclosure design.

Reviewer 2

The future milestones are well aligned with the goal of the project. The future work focus is more toward computational and analytical work so it would be good to consider a detailed scale-up experiment plan for achieving a 3-minute cycle time.

Reviewer 3

The proposed future research seems reasonable. It is not clear whether 3-minute process cycle time is for sensing device integration.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The project is well-aligned with the VTO objectives as the battery boxes will be one of the critical components for battery electric vehicles (BEVs) in the future. In addition, a multi-functional light composite battery box will help to reduce the overall weight of the vehicles significantly and thereby the project is vital to achieving the VTO objectives.

Reviewer 2

This project is relevant to the overall DOE objectives. The project clearly identifies the end application of a structural battery enclosure with a lower material cost and added functional properties that can make the enclosure safer and self-sensing.

Reviewer 3

The goal of this project is to develop high-performance multi-functional composite materials, which are highly desired for vehicle manufacturing.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The funding amount is sufficient to develop the technologies.

Reviewer 2

The team has the necessary resources for carrying out the project.

Reviewer 3

The resources are excessive to achieve the remaining milestones for the project and more novel research output would justify such a large budget.

Presentation Number: mat199
Presentation Title: Ultra-Lightweight Thermoplastic Polymer/Polymer Fiber Composites for Vehicles (Inter-Lab Project)
Principal Investigator: Kevin Simmons, Pacific Northwest National Laboratory

Presenter

Kevin Simmons, PNNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

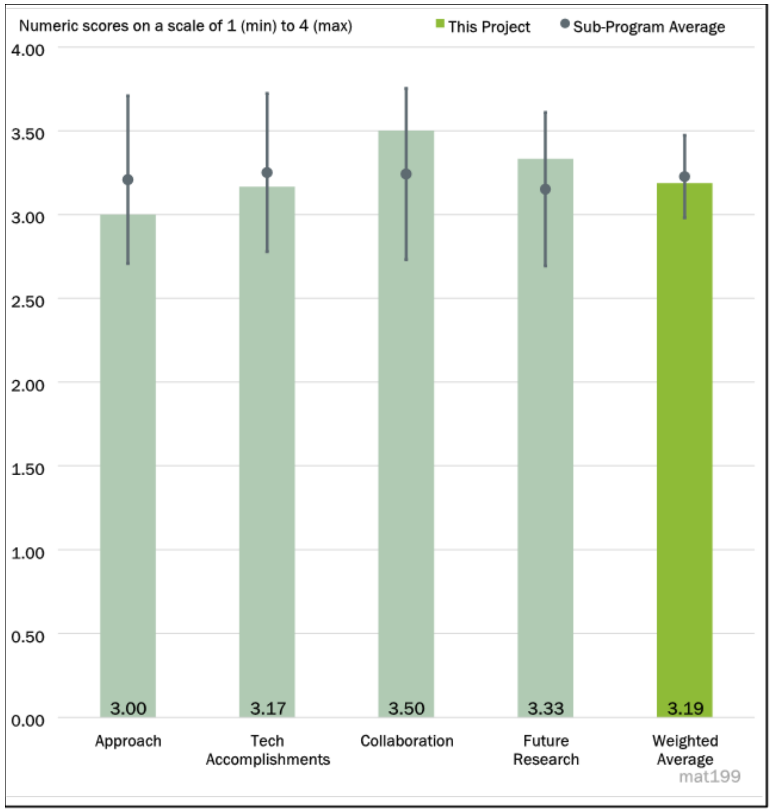

Figure 5-14 - Presentation Number: mat199 Presentation Title: Ultra-Lightweight Thermoplastic Polymer/Polymer Fiber Composites for Vehicles (Inter-Lab Project) Principal Investigator: Kevin Simmons, Pacific Northwest National Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

This project is well designed and targeting an important research direction by fabricating all thermoplastics-based composites. Some technical barriers such as polymer fiber preparation (showing 500 mega Pascals [MPa] tensile strength) and composite synthesis etc. have been addressed. The preparation of longer polymer fibers still needs further improvement.

Reviewer 2

Overall, the project is well designed, and the researchers either addressed or acknowledged major challenges. The progress in the presentation is showing that the project is on track. The project addressed some of the major issues of fiber-reinforced polymer composites. The replacement of commonly used fibers (glass fibers or CFs) with thermoplastic fibers has two major advantages: enhances the adhesion strength between fibers and matrix and more sustainable approach because of higher recyclability and lower embodied energy thereby lower carbon footprint. The key challenges of this approach will be: developing high performance thermoplastic fibers, maintaining the high performance of the fibers during composite manufacturing processes (e.g., injection molding, compression molding), and ensuring the adhesion between the fibers and matrix.

The milestone deadline for the first challenge (i.e., high performance fibers) is the end of this fiscal year, and the preliminary results show promising performances in terms of strength, stiffness, and failure strain of fibers.

The researchers plan to identify an optimal processing window for addressing the second challenge (i.e., performance loss during processing). The processing temperature window has been determined by examination of the thermal shrinkage behavior of ultra-high-molecular-weight polyethylene (UHMWPE) fibers and a small shrinkage of polypropylene (PP) fibers after the exposure to a high temperature (150°Celsius [C]) was shown. The mechanical performance decreases due to the shrinkage or the effect of exposure time on the shrinkage which is yet to be presented. The shrinkage of the material might be affected by the duration of heating, or the shrinkage might affect the mechanical performance.

The third challenge (i.e., ensuring the bonding between the fibers and matrix) was met by fiber coating on PP fibers and verified by component testing images of PP fiber/low-density polyethylene matrix. The effect of fiber coating on the improved performance remains to be demonstrated by the comparison of the mechanical performance between coated fiber/matrix composites and un-coated fiber/matrix composites. It is encouraging to note reasonably high-performance results presented for thermoplastic fiber/matrix composites with different matrix materials.

Reviewer 3

The project is not well designed to address the technical barriers based on a study published in 2013. The study needs to consider the trends seen in the automotive industry's acceptance for use of composite material for high-volume manufacturing.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

All the milestones have been met as per the progress details commented in quarter 2.

Reviewer 2

The research team has made good progress in spite of some unexpected issues such as thermoplastics matrix-polymer fiber interfacial interaction were addressed. The new proposed approach by the team of using aqueous based maleated polypropylene dispersion for fiber treatment could improve the filler-matrix bonding.

Reviewer 3

The remaining listed challenges and barriers listed are yet to be appropriately incorporated into the project plan. A concise story on how the project objectives were accomplished in a timely fashion remains also to be discussed.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer commented expertise from the PNNL and ORNL teams is highly complementary, and both teams are carrying out their research simultaneously and synergistically. The specific contribution from each team is very clear.

Reviewer 2

The reviewer noted that the work is divided into two parts, i.e., fiber manufacturing and processing with matrix. The fiber manufacturing is done by ORNL whereas the composite manufacturing with matrix and other processes by PNNL. The synergy provided by the collaboration of the two organizations seem to result in a good progress.

Reviewer 3

The reviewer said different tasks conducted at PNNL and ORNL were presented. A project plan consistent with the stated objectives and an appropriate timing needs to be developed jointly by two teams.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The future milestones are well aligned with the goal of the project. The fiber preforms for composite manufacturing undertaken by ORNL show high mechanical performance of fibers with a small shrinkage, unlike the more effect between them was anticipated. The PNNL team plan for composite manufacturing is to demonstrate a compression molding process with uniform heating and an injection molding process with chopped fibers and fabric fibers.

Reviewer 2

The reviewer said an understanding of the manufacturing cost remains to be addressed.

Reviewer 3

It would be good to discuss detailed research tasks for each team (i.e., PNNL and ORNL). It is likely that the future teamwork could achieve its targets.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The goal of the project is to develop materials and processing techniques for high performance polymer composites, which is directly relevant to the VTO objectives.

Reviewer 2

The project goal of development of a low-cost high-performance thermoplastic polymer matrix/polymer fiber composite system with good mechanical property and recyclability, is highly desirable for composites use in vehicle manufacturing.

Reviewer 3

The reviewer said the project goal may not support the VTO objectives as it is not clear how the outcomes of the project can be effective in acceptance and use of lightweight composites being proposed by the project for low-cost, high-volume production application.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The funding amount is sufficient to develop the technologies.

Reviewer 2

Resources appear to be fully utilized.

Reviewer 3

The team has all the necessary resources to perform the project.

Presentation Number: mat200
Presentation Title: Additive Manufacturing for Property Optimization for Automotive Applications
Principal Investigator: Seokpum Kim, Oak Ridge National Laboratory

Presenter

Seokpum Kim, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

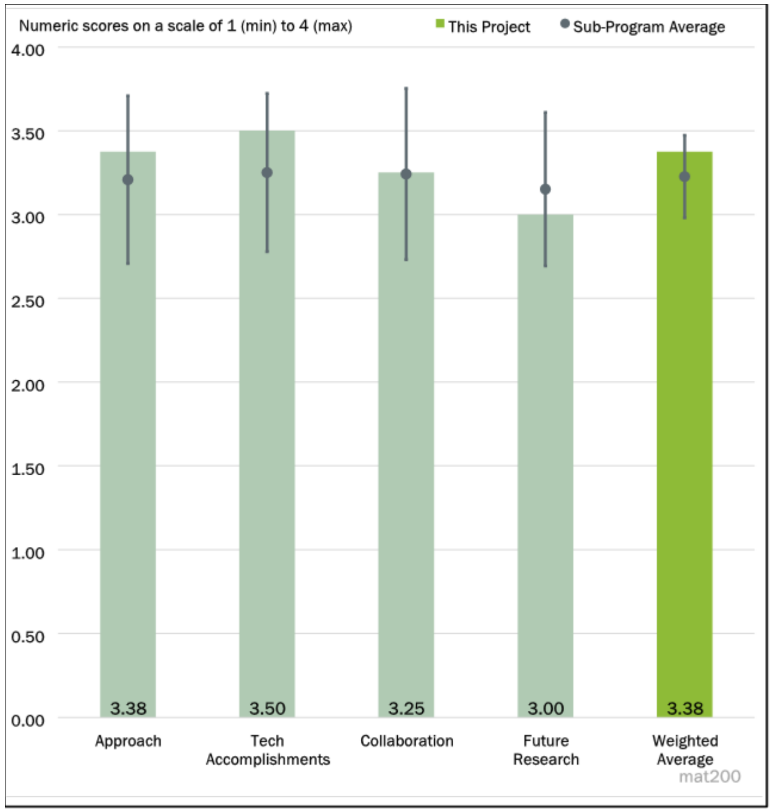

Figure 5-15 - Presentation Number: mat200 Presentation Title: Additive Manufacturing for Property Optimization for Automotive Applications Principal Investigator: Seokpum Kim, Oak Ridge National Laboratory

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This entire effort and the depth to which the researchers have taken is commendable and relevant. 3-D printing when it is brought into the mainstream of automotive composites manufacturing will be a game changer.

Reviewer 2

The printing of cellular structures with hybrid materials is of great interest to automotive industry for reducing weight and carbon footprint. The project is well designed to address the technical barriers. The project timeline is reasonable and the decision points for go/no-go are clear.

Reviewer 3

Project has a reasonable approach of developing ML and out-of-plane techniques. It would be good to see discussions/strategies on the cost reduction and mass savings project objectives.

Reviewer 4

The project is addressing the technical barriers in material options, bumper, and arm rest designs using geometric structures and ML to assist in optimal structure designs. The project approach of the consideration of two different products may instead focus on one product, i.e., either a bumper or an arm rest. It was not clear if the intent for the arm rest was for demonstrating the out of plane AM technique. The project is on schedule and some interesting work has been done. The development of the continuous path printing was a significant change in time for the part completion. It would be helpful to more discussion about the compounding of the ABS/CF blends with thermoplastic polyurethane, and how the blending could be damaging the CF or the ABS/CF dispersion within the mixture to determine the either homogenous or phase segregated type of dispersion. The test data is intriguing but evaluation of the strength properties beyond the modulus of the material would be useful.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The participants have done a wonderful job of breaking down the project to its essential subsets and then addressed each segment in a proper scientific manner.

Reviewer 2

The project has a good progress on part fabrication and design optimization.

Reviewer 3

The project plan is moving along as scheduled. The team is progressing on all their milestones. Technical progress has been made on each of the main tasks for the material, bumper, arm rest, and the machine learning. Testing has been commencing with impact property measurements with model predictions that have mostly good correlation.

Reviewer 4

The project is on track and has met the milestones as planned. The cellular architecture with design and printing flexibility has demonstrated advantages over traditional automotive manufacturing. The reviewer suggested that the project print different or hybrid cellular structures at different necessary locations.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The entire thought process and progress is extremely well organized in the presentation. The presenter was knowledgeable and addressed all the questions professionally and so reflected extremely well and coordinated team effort.

Reviewer 2

Partners have well defined roles in the project.

Reviewer 3

The project PI has been collaborating with Ford and UCLA. The project team members have knowledge and rich experience in 3-D printing and resources for scaling.

Reviewer 4

The project has been well coordinated with team members and so demonstrated a good collaboration between the partners. It is clear where UCLA and Ford are working to support the ORNL project with each providing data and part design details that feed into models for structure optimization through ML. Each partner is clearly identified on their project responsibility and accordingly contributing to the project.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The future research is well planned and anticipated to meet the milestones.

Reviewer 2

The presentation clearly defined a path forward for future work. It would be useful to incorporate aspects of total cost viability; sustainability; a better understanding of material engineering boundary conditions for the 3-D process; and a way to bring in the use of continuous directed fibers in the 3-D process.

Reviewer 3

The reviewer said the team may consider a comparison with baseline commercial products.

Reviewer 4

The proposed future work plan is clearly laid out. The material testing needs to include a little more detail on the contributing factors to the material changes. It is not clear whether the material changes are based on rule of mixtures of a stiff material with a soft material or an effect of blending the melt mix together. An understanding on where the properties are being contributed from, the CF, or the resin itself would be useful. Similarly, it is not clear whether the same effect of ABS alone can be obtained without the CF.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This is an extremely relevant project. It is a great work by the project team and the support of DOE VTO for pursuing this effort is appreciated.

Reviewer 2

Findings on AM potentially would facilitate the lower cost implementation of advanced materials for specific applications.

Reviewer 3

The 3-D printed cellular structure enables lightweighting and flexible manufacturing. The project supports the overall VTO objectives.

Reviewer 4

The project demonstrated that the design optimizations with structures that would only be available through AM for weight reductions with novel structure design. The team should compare their bumper or arm rest weight reduction targets that are trying to achieve to demonstrate the benefit of their approach.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

Project has the sufficient resources, and the project team is encouraged to find a way to fold in sustainability and a method to use continuous fibers into future projects.

Reviewer 2

Project is receiving sufficient support.

Reviewer 3

The resources at ORNL, Ford, and UCLA are sufficient for the project to achieve the milestones in a timely manner.

Reviewer 4

The team has done an excellent job in meeting milestones and achieving the results. They are adequately funded and have met all their milestones.

Presentation Number: mat201
Presentation Title: Additively Manufactured, Lightweight, Low-Cost Composite Vessels for Compressed Natural Gas Fuel Storage
Principal Investigator: James Lewicki, Lawrence Livermore National Laboratory

Presenter

James Lewicki, LLNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

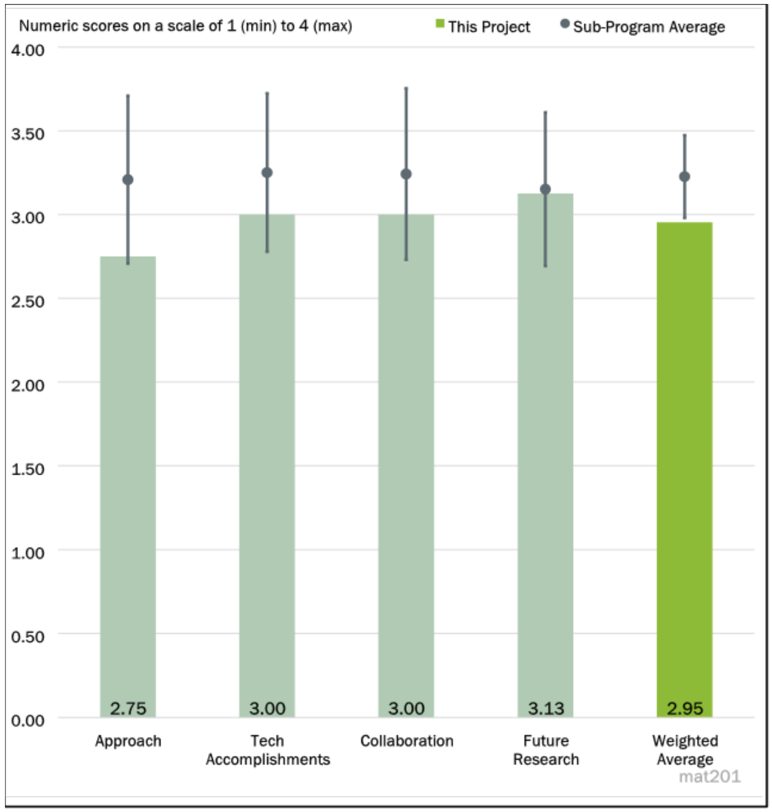

Figure 5-16 - Presentation Number: mat201 Presentation Title: Additively Manufactured, Lightweight, Low-Cost Composite Vessels for Compressed Natural Gas Fuel Storage Principal Investigator: James Lewicki, Lawrence Livermore National Laboratory

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The project includes an interesting approach to using different resin grades throughout the thickness of the tank. In principle this should potentially eliminate the cost for a separate gas barrier. However, there are general concerns on the scalability of the technology for high volume production. The time required to produce each tank needs to be adequately addressed and could be a significant impediment to future implementation.

Reviewer 2

The project has identified and addressed the key technical batteries for Type IV compressed natural gas (CNG) tanks. The CNG tank design is novel and the timeline is reasonable. Adding multiple nanofillers in resin is of great interest to tank liner and matrix.

Reviewer 3

The project aims to fabricate lightweight CNG tanks at reduced cost using an interesting AM technique. The team incorporates a hybrid approach using a nanomaterials enhanced resin composite. The project seems well-designed but major conclusions need to be based on sufficient data and experiments. The project technical barriers such as the lack of low-cost and high-volume manufacturing options for fabricating CNG tanks remain to be addressed.

Reviewer 4

It is expected the technology may find use in other composite manufacturing applications. The program needs to specify the resin matrix used and compare its pressure vessel performance to SOA resins used including to SOA towpreg laminate data need to be considered. It is rather easy to add fillers to unformulated epoxies to improve performance. While tensile strength and modulus is important but composite fracture toughness and shear strength are more critical measures. Permeability data is difficult to develop that is yet to be presented for the inner barrier. It is unlikely the approach can match the very high-speed winding accomplished with towpreg which yields superior performance over wet winding. The model study is necessary to support the benefit of its ability to better tailor fiber orientation. It is unclear whether fiber tension possible with the AM approach which is also critical factor for thick-walled larger tanks.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The project team appears to have made significant progress in the development of the multi-axis print head, which will be required to achieve further improvements in the manufacturability of storage tank designs. Several nano fillers have also been investigated to improve resin performance.

Reviewer 2

The project is on track and making progress toward the milestones as planned and the decision points for go/no-go are clear. Printing nanofillers of different materials is very challenging. The project team needs to address voids and filler agglomeration, which often leads to low mechanical properties and gas leaking. Cross-sectional characterization on the printed CNG tank is needed to show the defect distribution and find the solution how to print defect free CNG tanks.

Reviewer 3

The team made good progress on developing resin and structural development. Milestone progress appears to be on track, but printing and testing CNG tanks would be interesting. The gas barrier property and mechanical property of resin were unavailable including the print of CNG tank prototypes and its performance under similar conditions.

Reviewer 4

Material formulation work has progressed but key material properties tied to functional layer improvements remain to be measured. Laminate data is the best to consider for functional layer improvements because fiber will cause local orientation of the nanoparticles. In addition, fracture toughness under Mode I and II, shear strength, and hoop strength are critical properties. More progress has been made on the manufacturing side to enable tank geometry fabrication. It would be good to see results of the planned deposition rates as compared to high speed towpreg winding.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The project seemed to have a good coordination between MSC materials science LLC and the University of Illinois.

Reviewer 2

There is good collaboration across the current team. The reviewer recommended that existing tank producers are contacted to determine if all downstream production concerns have been addressed.

Reviewer 3

The collaboration with materials science has been going well. The relationship between printing parameters, microstructural defects, and mechanical properties needs to be established. ML may be helpful in this regard.

Reviewer 4

It is unclear whether MSC as an active participant in Slide 22 list of collaborators and responsibilities will fabricate a baseline tank for comparative testing.

Question 4: Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1

The development of a comprehensive cost analysis will be essential in order to fully evaluate the viability of the proposed technology.

Reviewer 2

The proposed future research makes sense. The project team may focus on defects and how to print defect free (or less defect) CNG tanks/samples. Burst testing is also essential for validating the additively printed CNG tanks.

Reviewer 3

The proposed research seems to align with the project aims very well. The team may consider the sensitivity analysis of a wide range of parameters. The reviewer suggested that an optimized resin design and composite will play a critical role in designing CNG tanks.

Reviewer 4

More information on the graded structure approach is necessary. It is unclear whether discrete layers are shown in Figure 6 or the composition changed/graded was without any basis. Optimized tool path will be of interest to help justify the manufacturing approach. As the static strength alone is not sufficient to predict fatigue and damage tolerance effects, hybrid printing would be of interest, potentially for other part geometries.

Question 5: Relevance: Does the project support the overall VTO subprogram objectives?

Reviewer 1

The project scope supports current VTO mission objectives.

Reviewer 2

The project supports the VTO overall objectives. CNG tanks help decarbonization and weight savings for vehicles. The proposed multi nanofillers help strengthen CNG tank matrix and liner.

Reviewer 3

The project goals align with the DOE objectives. Developing of lightweight CNG storage tanks with reduced cost has significant benefits for commercial natural gas fueled transportation.

Reviewer 4

The project does advance composite materials formulations and new manufacturing methods. It is unclear whether the approach will exceed SOA composite tank manufacture both in performance, cost, and manufacturing rate. The materials and manufacturing method developed may find use in other DOE focus areas.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

There are sufficient resources deployed on the project although further validation of the commercialization pathway is recommended through additional external review.

Reviewer 2

Lawrence Livermore National Laboratory and Materials Sciences have the required printing, characterization, and testing resources for the project to achieve the stated milestones in a timely fashion.

Reviewer 3

The resources of the project seem sufficient to achieve milestones in a timely fashion.

Reviewer 4

It is not clear what comprises of the continuous fiber additive manufacturing resin including its supplier. It was recommended to include a resin formulator or at least benchmark SOA resins used in this application. The use of ceramic nanofibers may provide some benefit if it can act as nano Z-pins in the laminate. This approach may be useful for making towpreg to be used in various composite applications.

Presentation Number: mat202
Presentation Title: 3D Printed Hybrid Composite Materials with Sensing Capability for Advanced Vehicles
Principal Investigator: Rigoberto Advincula, Oak Ridge National Laboratory

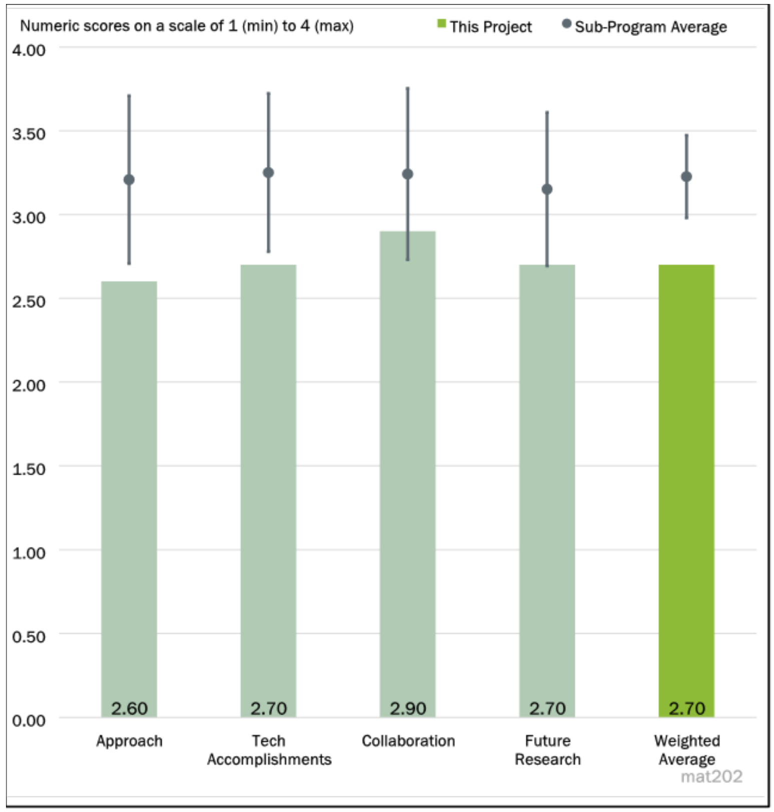

Figure 5-17 - Presentation Number: mat202 Presentation Title: 3D Printed Hybrid Composite Materials with Sensing Capability for Advanced Vehicles Principal Investigator: Rigoberto Advincula, Oak Ridge National Laboratory

Presenter

Rigoberto Advincula, PNNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The CF polymer interphase is a complex region that is not only dependent on chemical interactions but also the properties and structure of the 1-50 nm interphase region. The important factors of the failure mode generated on the cured interphase relating to the CF polymer adhesion to the composite properties. remain to be considered in this research. The methodology for measuring CF polymer adhesion, interphase characterization, and failure mode needs to be identified and discussed.

Reviewer 2

The project has a reasonable approach. Three-dimensional (3-D) printing of continuous fibers and sensor embedding can potentially expand the application of the composite 3-D printing technology. It would be good to consider the scale up challenges of the CF surface treatment and comparison with commercial products.

Reviewer 3

The reviewer remarked the approach appears to be reasonable.

Reviewer 4

The approach to printing continuous fiber with an epoxy matrix is interesting in spite of the printing of discontinuous fiber is not very novel. The results show poor strength gains with the included fibers and at 10%

loading the strength drops significantly. This volume fraction would be very low to begin with and shows the approach may not be appropriate. It is not clear about the purpose of printing on a woven fabric. The cathode printing may be out of place and in what way does this relate to the rest of the program.

Reviewer 5

This project focuses on AM for developing prototype parts and digital manufacturing with a goal of high-performance parts from continuous fiber composites. As part of this effort, new materials development and simulation simultaneous with 3-D printing and provision for integrated sensor for health monitoring are being examined. The science of the work is good but the connectivity to the intended application is somewhat ill-defined.

Slide 13 provides a somewhat unclear schematic of where and how the sensors are embedded in an automotive part. It appears from the figure on this slide that these are in the frame structure. It was not clear what the premise of the component in terms of whether it is: (a) 3-D printed; (b) a stamped sheet metal frame incorporating a 3-D printed sensor or (c) a 3-D polymer/CF composite with integrated sensors. Despite any of these cases, it may be too optimistic to make assumptions that the 3-D printed part will meet the stringent structural requirements without providing any evidence. Critical materials development aspects such as crashworthiness, sensor integrity under different loading conditions etc. need to be considered.

The role of the fiber-polymer interface has been emphasized on Slide 9 with only experimental tensile data results while the interface data is presented as modeling results only. The term interfacial strength needs to be properly used by appropriately defining fiber-matrix interface or the composition of composites. The experimental data like ILSS or fiber-matrix pull-out etc. needs to be included to represent the intent of capturing interfacial properties.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The technical progress on the tasks identified has been satisfactory.

Reviewer 2

The progress on the four tasks has been good.

Reviewer 3

Key outputs and accomplishments were made for development of the 3-D printed inks with embedded sensors.

Reviewer 4

There has been some progress with an exception in the discontinuous fiber work shows poor performance. This may be an issue with defects rather than interfacial strength but the results are no promising given that many vinyl esters can reach the tensile strength of the highest values without any carbon. It may not be appropriate to use epoxy as the performance is low to begin with and therefore the improvements are not substantial. The cathode printing does not fit with the project scope limited to composites. It is not clear how the team used epoxy and chopped CF to demonstrate up scalability of the process and show that continuous CF can be printed and scaled. It is not applicable for continuous CF and the demonstration on a woven and preimpregnated fabric does not contribute to the project goals.

Reviewer 5

The science of AM, careful printing experiments, and amine chemistry is well developed. The science of the work is good, but the connectivity to the intended application is rather weak.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

It is not clear whether the team is planning to consider to partner with a product customer for technology demonstration.

Reviewer 2

Reasonable contribution and collaboration between project partners were observed.

Reviewer 3

The distribution of resources is not clear.

Reviewer 4

The collaboration appears to be good based on statement made at the presentation “The coordination between ORNL and UNT [University of North Texas] is seamless and beyond the regular meeting, a lot of discussions and joint experiments are done in-between group members- email and calls (zoom).” Additional quantitative data would have been useful for the evaluation.

Reviewer 5

The collaboration between ORNL (different units) and UNT seems to be based on UNT expertise in interface and embedded sensors. The collaboration seems to stem from prior work done by the researchers in this area, although the compelling reason for this collaboration was not clear from the briefing.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The leap to a demonstration with larger structures and optimized formulations appears to be too large a step considering what has been accomplished to date on the materials side.

Reviewer 2

Good plan in general.

Reviewer 3

Well-outlined proposed future research.

Reviewer 4

The future work is not clearly articulated since the current material performance is poor and the printing of continuous CF remains to be technically accomplished.

Reviewer 5

The future work is built upon current work and here are some of some things to consider of which some may be applicable for the overall project goals with no substantive quantification or basis for the metrics:

- Demonstrate optimized continuous CF-epoxy 3-D printing into larger structures with optimized formulations: appropriate optimization metrics to be developed based on the rationale for the selection of target size and shape large structures;
- Investigate long-term thermo-mechanical properties of CF/polymer composites tandem with simulations using FEA and genetic algorithms for optimized 3-D printing methods: the vehicle crashworthiness needs to be considered for vehicle applications for the relevance of the study to the intended application. Thermo-mechanical properties with target metrics need to be included as well.
- Investigate other modes of surface modification of CF including use of other sizing and surface modifiers (silanes, phosphonates, crown ethers, etc.) with various weight % CF/epoxy composites in a continuous CF/epoxy 3-D printing system: the rationale behind surface modification for improved interface and weak interface (for energy dissipation) need to be clear.
- Sandwiching of 3-D printed sensor (zinc [Zn], vanadium, molybdenum, etc.) and develop a high-resolution sensor with the epoxy/CF composite.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The ability to utilize in-situ sensing to evaluate CF-polymer composite properties and their changes with exposure to various environments is an important goal for increased use of polymer composites in various structural applications.

Reviewer 2

Project addresses challenges in vehicle lightweighting.

Reviewer 3

The work is relevant. Performance results of printed vehicle structures with continuous fiber reinforced composites compared to poor performance obtained for vehicle structures with discontinuous fiber reinforced composites is necessary to determine the overall project impacts.

Reviewer 4

Addressing earlier comments is necessary to make this relevant to the program objectives. Presently it is a nice science study, with a big gap to reality.

Reviewer 5

The reviewer had no additional comments.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The team seems to have adequate resources in chemical aspects, 3-D printing, modeling, and simulation, and the needed tools to address the objectives.

Reviewer 2

The qualifications of the four investigators (Prof, Ph.D, grad, undergrad and what science or engineering background) are not identified nor is the percent time devoted to this project identified making the evaluation of the resources very difficult.

Reviewer 3

Resources are sufficient.

Reviewer 4

Resources are sufficiently utilized.

Reviewer 5

The reviewer stated progress is not promising and the program seems to be in too many directions, i.e., discontinuous fibers, continuous fibers, interfaces, sensors, and batteries. Minor impacts across a range of topics can be avoided by selecting some and do it well rather than trying to make all.

Presentation Number: mat203
Presentation Title: Low-Cost, High-Throughput Carbon Fiber with Large Diameter
Principal Investigator: Felix Paulauskas, Oak Ridge National Laboratory

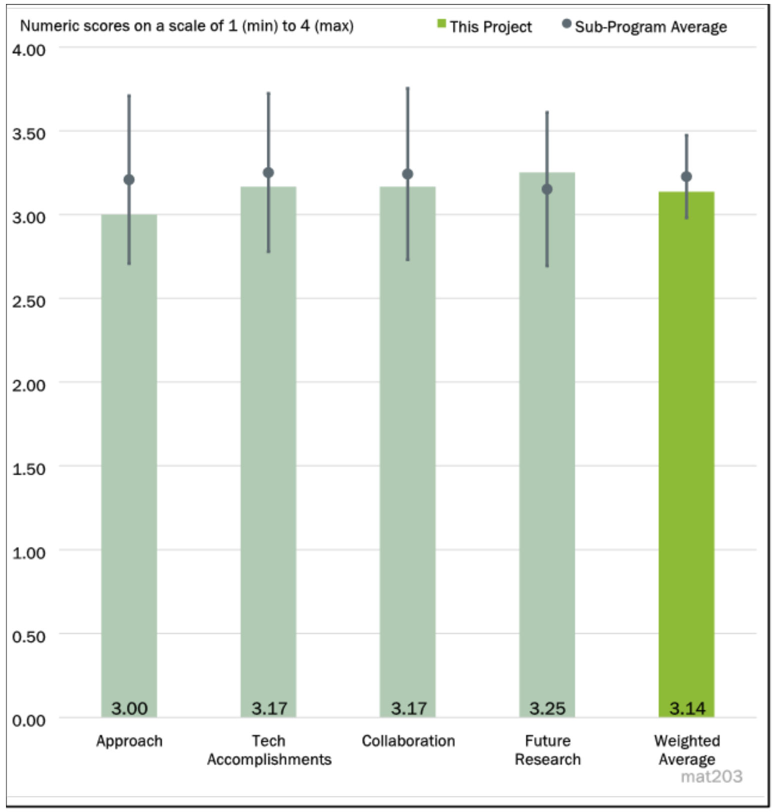

Figure 5-18 - Presentation Number: mat203 Presentation Title: Low-Cost, High-Throughput Carbon Fiber with Large Diameter Principal Investigator: Felix Paulauskas, Oak Ridge National Laboratory

Presenter

Felix Paulauskas, ORNL

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The project aims at lowering the cost of CF feedstock production. The approach is to increase fiber diameter and use atmospheric plasma oxidization to convert PAN fibers to CF. Plasma will accelerate the oxidization process and help oxygen penetrate deeper, particularly for more difficult to fully oxidize thicker fibers.

Reviewer 2

This project is difficult to evaluate because of the external factors such as changing collaborators, economic factors etc., beyond the control faced by the project team.

Reviewer 3

The project has identified and addressed the technical barriers. The timeline is reasonable and the targets are achievable as planned. The bigger diameter PAN precursors with plasma oxidation are expected to reduce the cost and find the applications in vehicle lightweighting.

Reviewer 4

It is useful to pursue alternate precursor fibers to produce low-cost CF given the much lower performance targets of interest for vehicles. Due to constraints regarding fiber availability from supply chain partners, it may we useful to explore more deeply effect of carbonization processing on properties. Large fiber diameter should not be an area of focus for this project, instead compression strength in composites should be measured if it is a goal.

Reviewer 5

The project Mat203 target is good as it aims to produce CFs from large diameter textile PAN. The approach utilizes their unique capability of plasma oxidation. Technoeconomic analysis needs to be completed after large diameter fibers become available. It will be helpful how cost benefits can be achieved by using larger diameter textile PAN fibers to demonstrate the benefit of using larger diameter textile PAN that is still conceptual today.

Reviewer 6

The use of a larger diameter CF is important and would be particularly useful in pultrusion where small cross section of current fibers requires too many tows to fill even a small tool. The approach has changed due to significant impacts on the project caused by COVID. It is not clear whether the team has considered pitch fibers which have the larger diameter and exceed the specified properties. In addition, consideration of any alternative approaches that could be investigated to reduce the generally higher cost of these fibers was not clear.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The team made good progress. The team produced 50% larger diameter CF. The year 2 cost target was not reached but shown to be achievable. The project could have achieved the if Dralon's Acrylic used as precursors supplied by Dralon were operational and not shut down due to Covid-19. ORNL team is working on alternative providers.

Reviewer 2

The progress has been satisfactory taking into account the external factors.

Reviewer 3

The project has identified a new supplier for bigger diameter PAN precursors. The preliminary results on plasma oxidation of the large diameter PAN are encouraging.

Reviewer 4

The project could have met the goals if the available of Dralon fibers were viable. It was suggested for ORNL to spin their own demo fiber by using their in-house capability.

Reviewer 5

Carbon fiber production from large diameter textile fibers has been conducted despite an issue of acquiring large diameter textile PAN. The CF properties are great for this new type of large diameter fibers, and it requires several adjustments for optimizing the oxidation condition. It meets VTO low-cost CF target. Some of the milestones are delayed mostly due to unexpected issues of acquiring fibers. It was not clear about its cost advantages as well as volume to utilize large diameter textile PAN. Larger diameter vs. smaller diameter textile PAN fibers difference may not be much if comparisons were mass based. The achieved CF diameters in this project are 6-8 µm range, which indicates high stretching is happening during the process. The benefits will be clarified if simple cost comparison as well as comparison in some other factors (environmental impact, availability etc.) are made between conventional textile PAN vs. large diameter textile PAN.

Reviewer 6

Given the availability of the original precursor the team has made good progress by securing other materials. The Sudamericana de Fibras fibers do not appear to be viable and the cross section is expected to be bad for packing and obtaining high fiber volume fraction.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer remarked the ORNL team is working hard to reach out and find the alternate feedstock providers. This awkward situation reflect this country’s supply chain issues.

Reviewer 2

Alternate collaborators and precursor materials have been identified and brought into the project.

Reviewer 3

The collaboration between ORNL and 4XT/4M has been going well. The project is also seeking U.S. suppliers for bigger PAN precursors.

Reviewer 4

The original team had potential for strong collaboration. It is not clear about the potential interest from traditional CF suppliers, Hexcel, Toray, Taiji, etc. Also if there is a market for low strength/modulus CF and why they do not make it.

Reviewer 5

The collaboration among ORNL, 4X technologies, and textile PAN providers are necessary for this project. They will eventually need to secure a provider of large diameter textile PAN fibers to avoid the current unforeseen situation in the future.

Reviewer 6

The team is working to integrate new suppliers.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The proposed work appears to be reasonable.

Reviewer 2

It is assumed that adequate material and process models have been developed and are being used to guide this project. The evaluation of resin infusion and interfacial properties should be done through modeling and simulation.

Reviewer 3

The proposed future research makes sense and the targets are achievable. The project has clearly defined the decision points for go/no-go.

Reviewer 4

More development on true market and cost projections for this grade of fiber would be good to have to determine if market forces can meet the demand.

Reviewer 5

The future research plan is well mapped out after a stable provider of large diameter dry spun PAN fibers has been identified.

Reviewer 6

There is considerable risk in the future work given a lack of fiber suppliers. The Asian company that is supplying precursors is most likely not able to manufacture larger diameter fibers.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

Carbon fiber has wide applications in energy efficiency and renewable energies. The proposed efforts of using plasma method to improve process efficiency and lower the cost support overall VTO subprogram objectives.

Reviewer 2

The ability to develop lower cost CFs is critical to achieving national light weighting and energy efficiency advances,

Reviewer 3

The project supports the overall objectives. Low-cost CFs are critical to fuel efficiency and EV drive range.

Reviewer 4

It is likely that low performance CFs has little market pull unless it is $2-3/pound to compete with glass where modulus is needed over strength.

Reviewer 5

The project is relevant to VTO if low-cost CFs from low-cost large diameter textile PANs can be made. It could then open some possibility of using these CFs for vehicles in the future.

Reviewer 6

The use of a larger diameter CF is important and would be particularly useful in pultrusion where small cross section of current fibers requires too many tows to fill even a small tool.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The project lacks the resource needed to accomplish the planned technical milestones.

Reviewer 2

It is difficult to judge the adequacy of the resources in the absence of detailed effort distribution of the project team members.

Reviewer 3

ORNL and 4XT/4M have the sufficient resources for the project to achieve the milestones in a timely manner.

Reviewer 4

The resources may not meet the needs given the drop-off in precursor availability from partners. It was suggested for a better program ORNL to buy the polymer and spin their own controlled fiber for processing.

Reviewer 5

The resource is adequate.

Reviewer 6

The resources are sufficient.

Presentation Number: mat204
Presentation Title: New Frontier in Polymer Matrix Composites via Tailored Vitrimer Chemistry
Principal Investigator: Tomonori Saito, Oak Ridge National Laboratory

Presenter

Tomonori Saito, ORNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

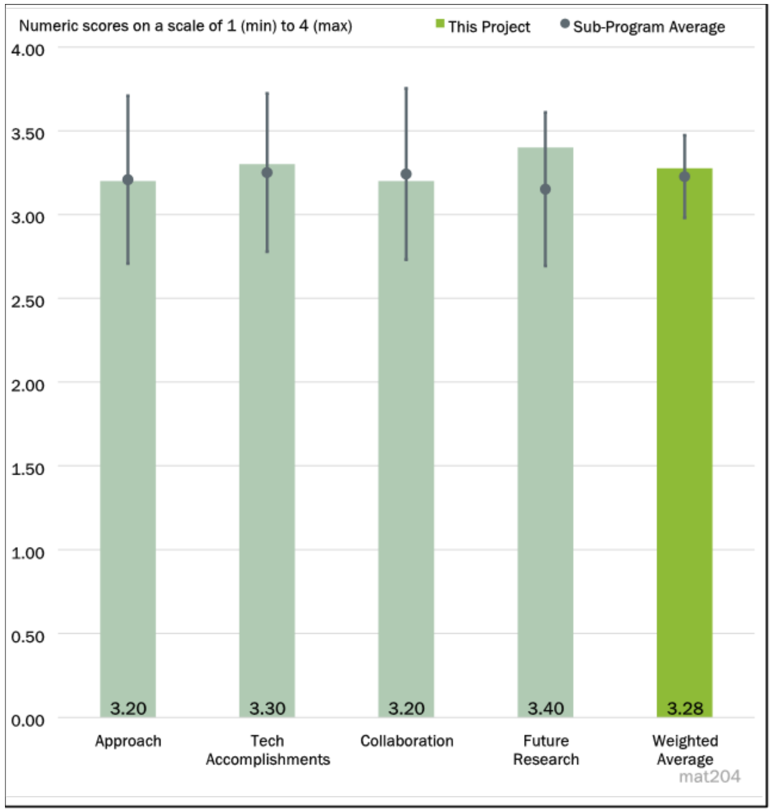

Figure 5-19 - Presentation Number: mat204 Presentation Title: New Frontier in Polymer Matrix Composites via Tailored Vitrimer Chemistry Principal Investigator: Tomonori Saito, Oak Ridge National Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The technical approach is well defined and able to demonstrate a pathway to creating a recyclable polymer system. Milestones are reported to be on track and performance targets are being met.

Reviewer 2

The vitrimer formulation developed in the project has shown equivalency with standard epoxy and vitrimer epoxy for the neat polymer case. The reprocessing benchmarks set out as a goal has been achieved. Several performance and property measurements for the next vitrimer work started remain to be completed. They are: moisture absorption, effect of moisture absorption on mechanical properties; fatigue resistance; creep resistance; freeze-thaw exposure; and surface energy. The surface treatment and/or sizing that would be used with carbon or glass fibers need to be identified. These required additional measurements would indicate that this vitrimer could perform equal or better than conventional epoxy.

Reviewer 3

It is one of the best presentations in this year AMR meeting. Project objectives along with supporting work have been well stated.

Reviewer 4

Project has had success with key objectives such as vitrimer synthesis, forming and testing samples, reprocessing, and repair. A thermoplastic matrix resin such as nylon would most likely provide superior performance at lower cost. The greatest distinction for this effort seems to be the ability to dissolve the matrix in several solvents to recover the fiber. It is not clear whether the polymer is recoverable from the solvent or is it now hazardous waste.

Reviewer 5

The project is well designed and the proposed timeline is very reasonable. A working polymer resin has been developed, which will be further integrated with CFs to fabricate target carbon fiber reinforced composites (CFRC)s via prepregs and compression molding.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The results presented show that the new materials can perform well against target with some flexibility to tune performance based upon the working temperature range. It is however recommended that an assessment of the business case commence earlier than the planned start date of FY23.

Reviewer 2

The base polyurea/epoxy vitrimer formulation shows high potential and has achieved some of the project goals.

Reviewer 3

Wonderful progress has been made on technical accomplishments.

Reviewer 4

Technical progress appears to be on track with the plan.

Reviewer 5

The research team has made good technical progress, including CF surface functionalization, polymer resin synthesis and exploration of processing conditions, and reprocessibility demonstration, etc. Better understanding of the contribution of urea vs. disulfide groups to the malleability/reprocessbility of the polymer resin is recommended.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The team breakdown was presented with detailed roles and responsibilities.

Reviewer 2

It is recommended to provide contributions of each member of the collaborating members and the time they devote to the project.

Reviewer 3

The team has accomplished an excellent summary of findings on a good collaboration and coordination of project activities.

Reviewer 4

Collaboration with potential industry partners such as Hexcel, Huntsman, and Hexion is anticipated to commence soon.

Reviewer 5

The contributions from industry (providing CFs and resin building blocks) and national labs (polymer and composite synthesis, property study) are clear.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The future work program is clearly defined. The project would benefit from benchmarking against competing technologies in order to determine the commercial viability of the chemistry being developed. A comparison with thermoplastic polymers would be useful as the targeted performance appears closely aligned to these materials which are already recyclable.

Reviewer 2

The performance and property measurements such as: moisture absorption, effect of moisture absorption on mechanical properties; fatigue resistance; creep resistance; freeze-thaw exposure; and surface energy need to be included in the coming year. Results would indicate whether this vitrimer could perform equal or better than conventional epoxy.

Reviewer 3

Future research is well stated.

Reviewer 4

The proposed future research is important. It would be good to consider the environmental durability of this material, UV and water effects, and creep behavior. It is not clear whether the material can self-heal and repair microcracks that may reside in hydrogen storage tanks.

Reviewer 5

The proposed future research is very clear and would directly contribute to the final goal of this project. Given the current progress, the future work is anticipated to achieve its targets.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The project reports to be aligned with the past report "From Light-Duty Vehicles Technical Requirements and Gaps for Lightweight and Propulsion Materials Workshop Report, February 2013."

Reviewer 2

This project success will be very important to achieve national goals of circularity and energy reduction.

Reviewer 3

The project is relevant.

Reviewer 4

The project relevance could be enhanced if sufficient material properties are obtained to provide route for material recovery for both fiber and matrix. Cost and environmental durability are two key questions to be addressed.

Reviewer 5

The goal of this project is to develop fast-processable, repairable, recyclable and affordable carbon fiber reinforced polymer (CFRP), which are highly desired for vehicle manufacturing, thus supporting the overall VTO subprogram objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The project resources and funding appear to be sufficient to complete the remaining milestones.

Reviewer 2

Resources appear to be adequate but the percent time allocated to each of the project participants needs to be identified.

Reviewer 3

Resources were sufficiently utilized.

Reviewer 4

It appears the team has adequate resources for the project.

Reviewer 5

The team has the necessary resources to achieve the proposed milestones in time.

Presentation Number: mat205
Presentation Title: Adopting Heavy-Tow Carbon Fiber for Repairable, Stamp-Formed Composites
Principal Investigator: Amit Naskar, Oak Ridge National Laboratory

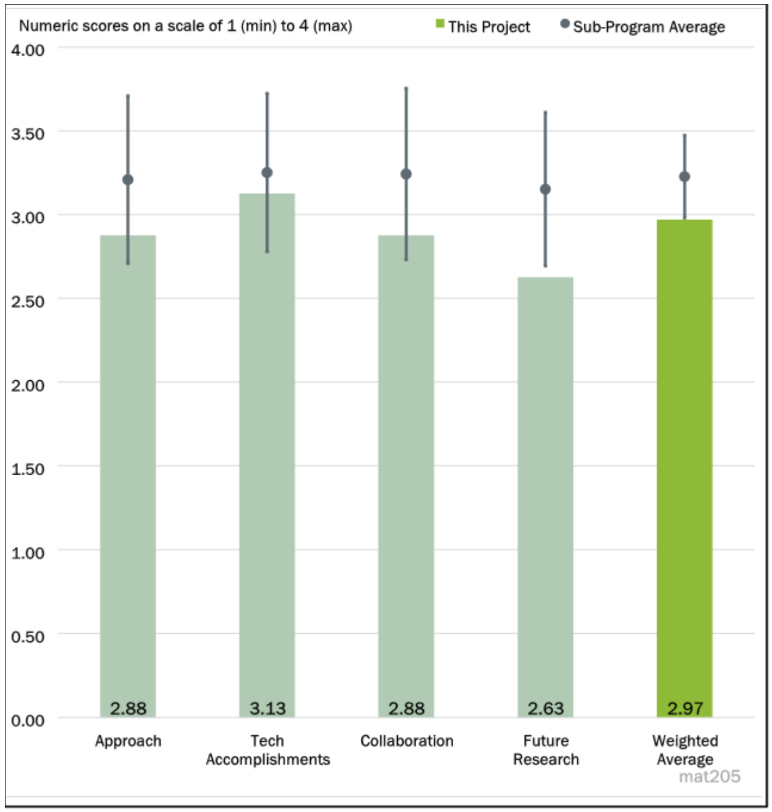

Figure 5-20 - Presentation Number: mat205 Presentation Title: Adopting Heavy-Tow Carbon Fiber for Repairable, Stamp-Formed Composites Principal Investigator: Amit Naskar, Oak Ridge National Laboratory

Presenter

Amit Naskar, ORNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The project appears to be lacking nano-level information about the CFr structure and atomic and molecular information relevant to the factors important for polymer adsorption and nucleation. For example, the size and orientation of the graphite crystallites changes with the CF modulus, i.e., larger, and oriented more parallel to the CF surface. The sites for chemical functionalization are the edges of the graphite crystallites and the polymer molecular weight (Mw) and its distribution would be important. Low Mw of the polymer would migrate faster to the CF surface preventing the higher Mw from nucleating in an optimum manner.

Reviewer 2

The approach adopted in this project comprises of understanding interfacial chemistries, their effect on composite processability, develop stamp-formed structures and perform technoeconomics, covering the all aspects of material and process development. It contributes to overcoming most of the technical barriers identified.

Reviewer 3

Milestones and go/no decision matrix are clear.

Reviewer 4

The work is interesting but seems to be a bit unfocused by bringing carbon nanotubes (CNT)s into the program. It can add significant complexity and environmental, health, and safety concerns as well as cost that may not be compatible with vehicle applications. The strength values obtained for the baseline are impressive although very low but with the notable % gain. Sub 100MPa strength is below for a quality epoxy resin and the reduced strain to failure may limit the significance. Data sets need to be large to generate statistically significant data. The bound PP on the fiber surface, may not Xylene will dissolve PP and 'image b' appears to show some material at the bottom of the flask. It is not clear how the PP was bound to the fiber surface and the technique used.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The project has made good progress on the processing aspects of the project. It appears that nano-level information about the CF structure and atomic and molecular information with the polymer as well as the polymer Mw are not considered.

Reviewer 2

The project has made good progress on process development and mechanical performance testing. It would be good to see how this composite performs with equivalent materials especially in the automotive context.

Reviewer 3

Some of the key issues with fabrication process have been addressed along with appropriately identifying characterization methods with nano-indentation mapping.

Reviewer 4

The program needs to have a focus with a few approaches instead to accomplish the goal. The actual innovation needs to be clear for this level of investment because the CF mats are commercial and the laminating process is not innovative. The It is not clear how the PP was bound to the fiber surface and the technique used. It is not clear whether the project goal is it to modify the fiber surface, to manufacture random CF mats, or to add CNTs for interfacial strength. The objective of 1GPa nylon strength seems optimistic given that the high-count carbon tows being used would require very high-volume fraction. Similarly, the currents results indicate the objective to reach 500 MPa may be optimistic as well. The surface chemistry and the methods to attain improved interfacial strength are important and CNTs may not be a good idea with little commercial viability.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The team appears to be adequate. The background and expertise of the team members and the time that they have devoted to the project need to be identified. This information would be helpful to determine the rating of the collaboration of the team members.

Reviewer 2

Good collaboration is with University of Tennessee (UT). It would be great to see OEMs participate at least in an advisory capacity for such a large project.

Reviewer 3

Collaboration appeared reasonable in supporting project objectives.

Reviewer 4

The work distribution is not clear. It would be good to indicate whether the work performed at UT is by graduate students or ORNL. The CF mats are commercial so the actual advances or innovation being offered by the team may be small.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The formation of chemisorbed species has been identified as an important project future research area. Identification of the surface properties important for functionalization and nucleation including specification of analytical techniques to quantify them is necessary. The change to a nylon matrix need to be explained in sufficient detail. The processing and the development of the cost model seem premature.

Reviewer 2

The plan is good for the next set of activities.

Reviewer 3

The proposal and evaluation are detailed.

Reviewer 4

High future milestones are unlikely to be met based on progress made so far. It is unclear how strong ideas would improve the performance.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The project supports the VTO subprogram objectives.

Reviewer 2

Development of thermoplastic based CFRP is relevant research for the VTO portfolio.

Reviewer 3

The study is aligned with VTO objectives.

Reviewer 4

The program is relevant but the properties being generated are not so far. The use of CNs is not relevant to vehicles and the laminating process proposed required 30 minutes in the press which is not relevant to high volume components.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The resources directed to the projects are very difficult to judge based on the available information.

Reviewer 2

Sufficient resources are available to complete the rest of the project.

Reviewer 3

Resources are appropriately utilized.

Reviewer 4

The budget is high for the results generated.

Presentation Number: mat206
Presentation Title: Soft Smart Tools Using Additive Manufacturing
Principal Investigator: Jay Gaillard, Savannah River National Laboratory

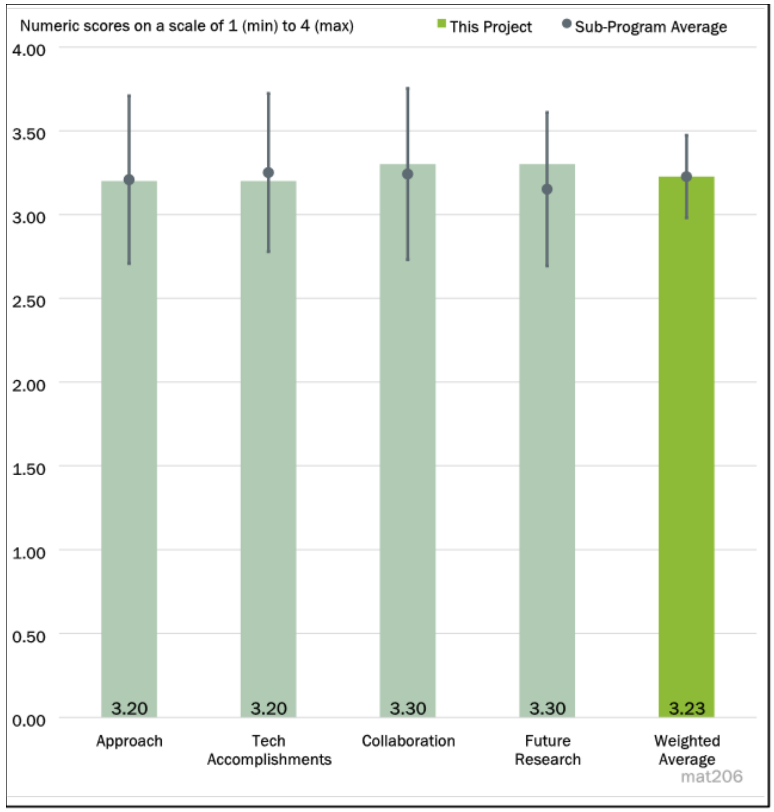

Figure 5-21 - Presentation Number: mat206 Presentation Title: Soft Smart Tools Using Additive Manufacturing Principal Investigator: Jay Gaillard, Savannah River National Laboratory

Presenter

Jay Gaillard, SRNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

Overall, it is a well-designed project. Technical barriers were sufficiently addressed and the project is well-planned. Sufficient studies on the temperature changes due to the different CNTs was a good study and it led to good mechanical improvements in the parts.

Reviewer 2

The technical barriers have been clearly identified for this project. The approach is reasonable and results are positive.

Reviewer 3

The project team used AM for smart tooling, which is an interesting approach. It would be interesting to know how microwave annealing helps sensing capability. The project aims to reduce tooling costs and curing times using AM techniques. Cost analysis would be interesting for the real application ability.

Reviewer 4

The science is interesting and may have use for other applications beyond the proposed use in tooling seems to be rather abstract. The tool application needs to be defined initially to follow and review the project. Stamping and matched profile tools are in compression, thus interlaminar tension strength is of little concern. The mold profile needs to be constrained in a press or coffin format for RTM tooling to be under transverse tension. It is not clear how the strain gage will be utilized and thermocouples to control the process besides monitoring. Traditional thermocouple placement or scanning of the tool after use to check dimensions may also be used. CNT use as a receptor is well established and so its use as an example may enable uniform heat distribution at the tool surface for more efficient composite cure. Poor vacuum integrity for this type of polymeric AM tooling has been a key issue in the related work by others and so a simple run for a leak check on vacuum bagged printed plate may be considered. The annealing may help solve this problem.

Reviewer 5

Savannah River National Laboratory (SRNL) project seeks to 3-D print CNT-coated carbon-carbon fiber (CCF) and post-process via microwave. The general approach is good, and potentially custom-designed 3-D objects with decent properties utilizing this specific microwave process could also be created. The project target is for tooling, which seems to have a gap for the goal and their plan. Careful selection of the resin, fiber loading etc. needs to be made if the tooling is the goal unlike the focus at this stage has been the demonstration of printing and microwave process. It is also not clear about the benefits of the composite tooling. To use composites for tooling molds, its life like metal tooling or low coefficient of thermal expansion (CTE) need to be known.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The project has good quantitative milestones and criteria to measure the success. All targets look to be successfully met. The microwave annealing is showing some very promising results in terms of tensile strength and temperature rate increases. The reviewer would like to know as a part of the undergoing durability studies, the durability target for the developed material and what level of durability would make this approach competitive with conventional tooling.

Reviewer 2

Progress has been good as well as the ability to incorporate strain and temperature sensors. The change from Nylon to polyaryletherketone (PAEK) is warranted to produce a more robust system.

Reviewer 3

The team made good progress compared to the project plan. It was interesting to note the tensile property after microwave annealing improved. A new stable ink formulation using fillers but the agglomeration of fillers that may have a detrimental effect on real-life applications need to be considered.

Reviewer 4

The printed TC using silver and CNT ink is interesting and should have other applications in smart structures. The microwave post processing enhanced with CNTs is also an interesting approach and may be more useful to support actual composite cure. It is simpler from a practical perspective to scan and measure dimensions after a molding cycle instead of printing a strain gage. It is not clear about the plan for dimensionally shape the mold in-situ.

Reviewer 5

The progress is good being able to successfully print CNT-coated CCF with improved mechanical performance after microwave processing. They have also made significant progress on adding sensor to the system. It was not clear if there are significant advantages in their approach. The traditional manufacturing and post-attachment of functions such as sensors may exhibit similar or even better performance. It was suggested to think through what the major advantages of the approach are compared to a conventional manufacturing with the same functionality.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The project has a good group of collaborators/partners that should help to push the research to commercialization. It will be interesting to see how the scale up of the CNT coating process goes with Mainland Solutions.

Reviewer 2

The research team made good collaboration for this research project with Clemson university and Mainland Solutions.

Reviewer 3

Mainland Solutions seems to be providing strong support to deliver on the 3-D printing filaments and embedded sensors. It is not clear whether Clemson will support tool design and requirements in addition to the mechanical testing already being provided. Critical concerns for RTM process include CTE dimensions and non-isotropic Z expansion in composites. Vacuum integrity and seals are issues with these fused deposition modeling FDM tools and so it is not clear whether tool cavity be placed in compression using press or coffin tooling. Also, it is not clear whether the tool will be heated to promote cure or the microwave oven cure will be done.

Reviewer 4

The project team has collaborated with others well. It may be important to get clear feedback from OEMs and adding them as a collaborator will be good for future, as stated in Clemson's role.

Reviewer 5

The reviewer said that data is lacking on the role of each team member, their expertise, and time devoted to the project making evaluation of this project difficult.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The future research is well-planned and is logically organized. The remaining barriers were identified and matched with the corresponding future work to address each of those problems. The use of CNTs in the sensor ink and for coating the CF, it would be good to evaluate the estimated cost of the different CNTs used for its commercial feasibility of the ink to make sensors. It is important to present the tech-economic analysis (TEA) results that will be performed for this work. Progress made over the next year in the plan for the continuous CF 3-D printed parts in PAEK matrix instead in a nylon matrix today, would be a valuable addition to the research.

Reviewer 2

Future research is reasonable considering accomplishments made to date. The project would be more valuable if a cost-model would be developed so that the economics of this approach could be monitored and area for cost reduction could be identified.

Reviewer 3

The team identified the problems and proposed future work to address them and barriers. The reviewer would like to see the stability of the tooling in different environmental conditions.

Reviewer 4

It is critical to select a demo part and accordingly tool design and requirements be considered to address key requirements. The criteria can vary widely based on demonstration case. Sensor work is interesting but for this application it is of little value compared to more proven traditional methods.

Reviewer 5

The future work for this specific scope is good. The choice of materials and composition may be not be appropriate for the tooling target. A map of specific target tooling and their desirable properties (thermal stability (CTE), thermal conductivity, and mechanical stability for repeated use etc..) may be developed.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

Increasing durability of 3-D printed tooling is relevant to DOE objectives and to the automotive industry.

Reviewer 2

The project nicely bridges materials and manufacturing areas.

Reviewer 3

The project aims to reduce the tooling cost that addresses the DOE missions.

Reviewer 4

Project is doing some interesting materials science which may have applications in smart structures. The application toward tooling is limited with the exception of using CNT’s and microwave to heat the tool for part cure.

Reviewer 5

The project is relevant to VTO.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The resources are sufficient to achieve the remaining milestones of the project in a timely fashion.

Reviewer 2

It is difficult to answer the question due to the lack of information about the expertise and time commitments of the participants

Reviewer 3

The team has sufficient resources to accomplish the project goals.

Reviewer 4

Sufficient time and funding to adequately design, fabricate and test a tool for taking advantage of the new technology to address the current very low Technology Readiness Level (TRL) work may not be there.

Reviewer 5

The resource is sufficient.

Presentation Number: mat207
Presentation Title: Multi-Material, Functional Composites with Hierarchical Structures
Principal Investigator: Christopher Bowland, Oak Ridge National Laboratory

Presenter

Christopher Bowland, ORNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

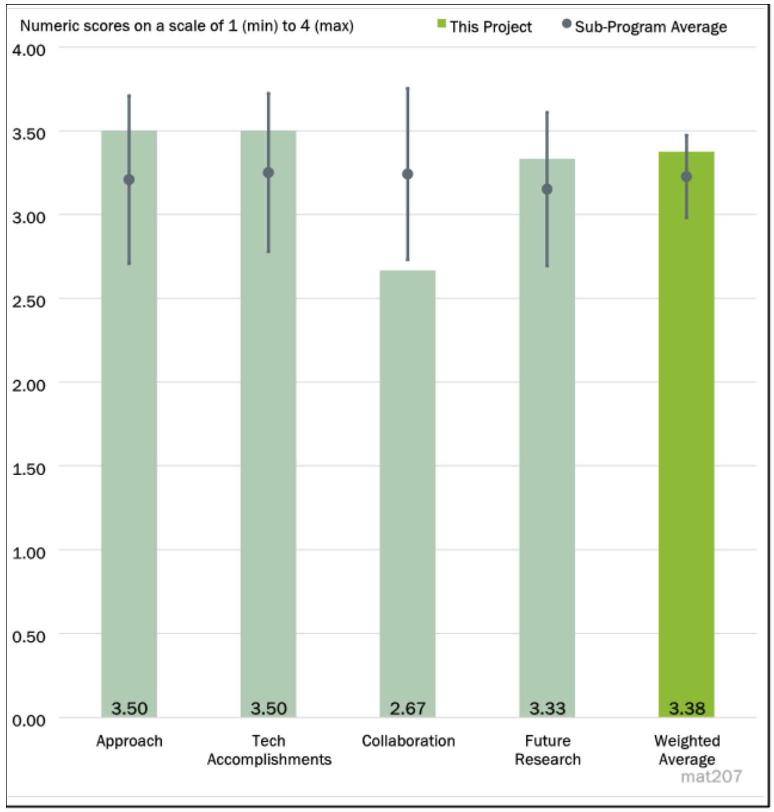

Figure 5-22 - Presentation Number: mat207 Presentation Title: Multi-Material, Functional Composites with Hierarchical Structures Principal Investigator: Christopher Bowland, Oak Ridge National Laboratory

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

Overall, this team has a good approach and plan. The project team has developed their own test to assess interfacial strength of the fibers in the polymer matrix. More work is necessary to demonstrate the measurement types can the test allow to measure.

Reviewer 2

Approach is well-established.

Reviewer 3

This project, compared to the others reviewed, has thorough data collection and analysis. Strong progress is evident and some level of success has been shown in energy harvesting, structural health monitoring, and interlaminar enhancements.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The project is approximately halfway complete and appears to be on track to complete its milestones successfully.

Reviewer 2

Great progress has been made on the interfacial characterization techniques and confirmation of nanofiber bridging.

Reviewer 3

Project shows significant results for all three approaches.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

All work in this project has been done by a single performer (ORNL), but plans to work with a subcontract collaborator in the second half of the project for fatigue testing.

Reviewer 2

Reasonable collaboration and coordination and the encouraging results from Columbia university were presented.

Reviewer 3

The work by Columbia University has not yet begun.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The future work plan includes well planned and diverse tasks, ranging from scalability studies to computational modeling and techno-economic analysis. The future work plan is well focused on tackling the critical barriers.

Reviewer 2

Excellent outline with supporting details.

Reviewer 3

Demonstration of laminate with low velocity impact, SHM sensor response, and reduced delamination zone would be good to see. Identification of SHM pick-up damage after the event by looking into change in applied excitation would be good to consider. In practice an auto garage needs to run a scan and trace potential damage location.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The project is well aligned with DOE objectives in composites for vehicle lightweighting.

Reviewer 2

The project is relevant to VTO objectives.

Reviewer 3

As this technology is low TRL, other more mature existing methods for energy harvesting, SHM, and property enhancement may be considered. Commercialization feasibility study will be important to determine relevance in comparison to current SOA methods.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

Resources are sufficient.

Reviewer 2

Results of the studies being planned at Columbia university is awaited.

Reviewer 3

The team has the adequate capability to conduct the research work.

Presentation Number: mat208
Presentation Title: Efficient Synthesis of Kevlar and Other Fibers from Polyethylene Terephthalate (PET) Waste
Principal Investigator: Daniel Merkel, Pacific Northwest National Laboratory

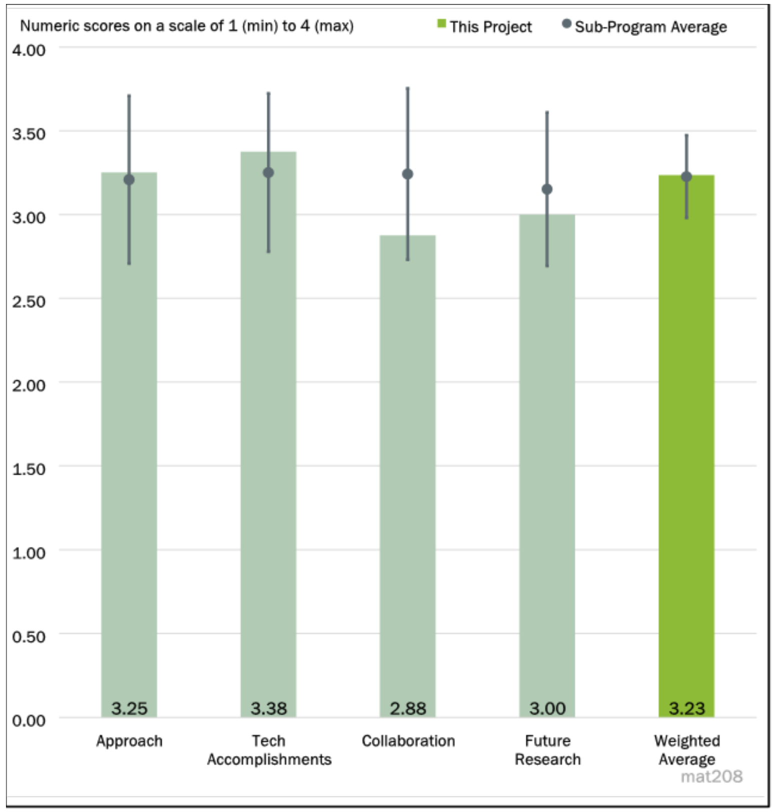

Figure 5-23 - Presentation Number: mat208 Presentation Title: Efficient Synthesis of Kevlar and Other Fibers from Polyethylene Terephthalate (PET) Waste Principal Investigator: Daniel Merkel, Pacific Northwest National Laboratory

Presenter

Daniel Merkel, PNNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The work had a good approach to use a mixed PET waste stream to synthesize aramid fibers with the potential to lower their cost. Good characterization work has been performed on the synthesized material prior to fiber spinning. All this information is very important to make the fiber spinning tasks successful.

Reviewer 2

The project addressed one of the major issues of fiber-reinforced polymer composites, i.e., the high cost of CF. Replacing commonly used fibers (glass fibers or CFs) with Kevlar-like fibers from PET plastic will help in: (1) creating a cost-effective alternative for carbon-based fibers and matrix and (2) a more sustainable approach because of higher recyclability. The key challenges of this approach will be: (1) developing high-performance fibers continuously without defects, (2) complete deconstruction and repolymerization of PET, and (3) ensuring the minimum hazardous by-products.

Reviewer 3

The approach to preparing kevlar or other fibers from PET waste seems very interesting as it could reduce the cost of fiber production and plastic wastes from the environment. The project team has already demonstrated the synthesis of aramid from PET and optimized the molecular weight by changing the amine structures. However, the major challenge that appeared to the reviewer is to prepare the fiber with optimum properties.

Reviewer 4

The timeline is reasonable; however, the team needs to be on the project timeline on fiber spinning which is critical to the proposed work. The mechanical properties of the fiber are necessity to demonstrate the performance of the materials following refinements. It would be reasonable to cast aramid films and test these to show the materials produced have good mechanical properties. Chemical analysis to show the obtained materials have the proper structure including nuclear magnetic resonance, and Fourier transform infrared or another technique for its purity is necessary in demonstrating the technique can yield high performance materials in the long run. It is noted that irregularities are often desired (see aramos fiber) in aramid fibers and therefore could provide a benefit if reproducible.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The team has quantifiable milestone targets to assess the success of the project. All milestones seem to have been successfully met and the project seems to be on schedule. There has been a slight delay in the fiber spinning task progress including some difficulties with that milestone but that is not surprising for this difficult task. It is good that the team has identified Washington State University as a collaborator to help with the spinning scale up and Oak Ridge National Laboratory to help with the dope characterization. These collaborations should help achieve the spinning milestone.

Reviewer 2

Good progress has been reported in terms of polymerization of various diamines at a small scale and synthesis of Kevlar polymer and other similar branched polymers. A partial successful fiber spinning is also reported but large defects in the fibers remain serious concerns.

Reviewer 3

The team has made good progress on the deconstruction of PET from mixed plastics and the synthesis of polyaramid. It would be great to see more progress on the fiber preparation and its properties, especially fiber with consistent diameters and geometries along the fiber length.

Reviewer 4

It is impressive to see PET recycled with considerable impurities into aramid. It is hard to judge the materials without chemical analysis or mechanical testing and therefore too early to comment on the success but the refinement and polymerization is a very strong accomplishment.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

There has been a good collaboration and coordination across the team. It was good to see that other entities have been involved to help with the spinning process.

Reviewer 2

The roles of ORNL and WSU project partners in this project has been limited and not well-defined as their roles come into the picture later in the project for the delivery of the spinnable polymers from the PET.

Reviewer 3

The team has established collaboration with ORNL and WSU on fiber production.

Reviewer 4

The team needs to have a formalized collaboration.

Question 4: Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1

The future milestones are effectively planned in a logical manner with an exception with the composite milestone. It was not clear how the fibers to be spun at WSU in 40-filament tows will be produced in high-tow lengths in order to combine the tows to get a sufficient fiber loading in the composite. This problem needs to be taken into consideration during the next year beyond this review stage. The cost target for the fibers is yet to be determined fibers although it was stated to be below the cost of CF. The cost of CF is also the milestones for other projects that may create a moving target for this project. This issue can be addressed when performing the techno-economic analysis.

Reviewer 2

The project has defined the most critical future steps, including studying various sulfuric acid and N-methyl pyrrolidone polymer concentrations, composite fabrication, and techno-economics analysis. However, the plan to counter the scale-up process remains to be covered.

Reviewer 3

The project team identified the challenges and demonstrated a future plan to address those issues well.

Reviewer 4

The future work plan needs to be clear and evaluation of mechanical properties is critical to show success. It would be significant if Nomex like properties were obtained although probably not VTO relevant.

Question 5: Relevance: Does the project support the overall VTO subprogram objectives?

Reviewer 1

This project is very relevant to DOE objectives. It aims to provide fibers for vehicle lightweighting at a competitive cost while also utilizing recycled waste streams.

Reviewer 2

The goal of the project is to develop kevlar-like polymers and fibers from polyethylene terephthalate plastic waste, therefore addressing the high cost and sustainability problem at the same time. Project also plan to study processing techniques for high-performance polymer composites, which is directly relevant to the VTO objectives.

Reviewer 3

The project supports the overall goal of the DOE mission and VTO objectives as their main goal is to prepare alternative CF from PET waste. Most importantly, it addresses the plastic waste pollution that will benefit the society.

Reviewer 4

Kevlar is not widely used in automobile applications and is therefore not a significant material. This could be a very important development with a consideration of the cost reduction in the approach. The issue is not will the cost of the raw materials for Kevlar but in the manufacturing for which the fiber spinning cost needs to be addressed. Alternative aramid fibers such as Armos (not many people are familiar with this technology developed by Russia in the Cold War) have far greater potential than Kevlar and so may be and considered to create disorder to disrupt hydrogen bonding to improve both processability and properties.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The resources are sufficient to achieve the remaining milestones.

Reviewer 2

The funding amount is sufficient to develop the technologies.

Reviewer 3

The budget is sufficient to meet the current milestones.

Reviewer 4

Funding level seems to be sufficient to excessive without any available budget information.

Presentation Number: mat209
Presentation Title: Bio-based, Inherently Recyclable Epoxy Resins to Enable Facile Carbon-Fiber Reinforced Composites Recycling
Principal Investigator: Nicholas Rorrer, National Renewable Energy Laboratory

Presenter

Nicholas Rorrer, NREL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

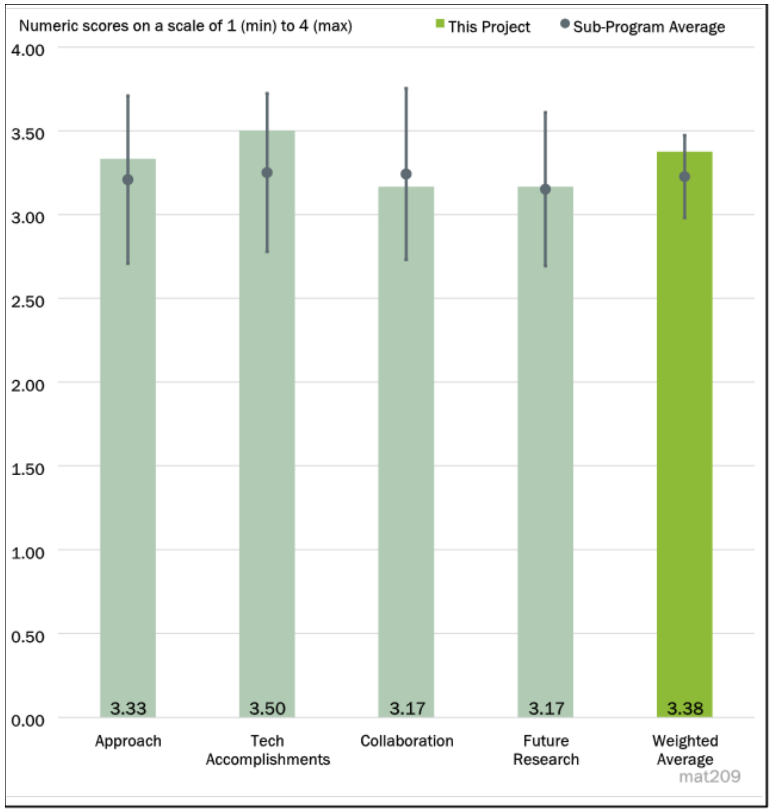

Figure 5-24 - Presentation Number: mat209 Presentation Title: Bio-based, Inherently Recyclable Epoxy Resins to Enable Facile Carbon-Fiber Reinforced Composites Recycling Principal Investigator: Nicholas Rorrer, National Renewable Energy Laboratory

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The bio-derived approach was well-designed and well-planned to address the technical barriers. The project has a logical approach of developing the adaptable networks, developing fiber sizing, validating the materials at scale, and performing the TEA.

Reviewer 2

The project aims to produce recyclable-by-design CFRCs that leverage a bio-derivable epoxyanhydride covalently adaptable network for better material and environmental performance. For this purpose, the main focus is on resin development and, later on, the demonstration of composite recycling. The approach is satisfactory.

Reviewer 3

The project aims to incorporate bio-based precursors using a covalently adaptable network to reinforce fiber that could lead to re-processible and recyclable lightweight composites for vehicle manufacturing. The project team recycled CF by losing the matrix. It would be more cost-effective if they could recycle both fiber and matrix to make closed-loop recycling.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

All technical accomplishments for this year are likely to be met and the project is on schedule. The TEA and lifecycle analysis (LCA) were excellent to include at this stage of the process to make sure the team is on the right track for commercialization. When reporting on the milestones achieved. It would be good to show the criteria of each milestone when reporting its completion for a better understanding of the metric of success for each. The quantitative target for each milestone should also be considered.

Reviewer 2

Successful resin material development and its recyclability have been demonstrated successfully in fiscal year 21. TEA/LCA also showed promising outcomes from the project. Also, all the milestones before the presentation submission date have been met.

Reviewer 3

The team delivered good results in synthesizing CFRPs and recycling of CF. A good progress has been made on composite scale-up, validation, and cost analysis. Additional results of the matrix mechanical properties and recyclability would be good to consider. One of the matrix components was linear poly(ethylene glycol)-based epoxied which are known to absorb water and can have detrimental effects on vehicle applications.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

There was a good list of collaborators on this project. However, it was unclear what specific collaborative efforts were being performed on this specific project to achieve the milestones. The collaborators listed in the presentation seemed more aligned with larger consortium instead of collaborators specific to this project.

Reviewer 2

Good coordination between the national labs, industry partners, and universities is evident in work. A more task-specific work distribution is needed to discuss the responsibilities of so many partners involved in this project.

Reviewer 3

Good collaboration exists with the National Renewable Energy Laboratory (NREL) It would be great to have industry partners to validate the data and large-scale composite manufacturing.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The future research milestones are logical to address the remaining challenges and barriers that were clearly stated. For future work, it might be good to compare the team material performance to other vitrimers that have been developed instead of comparing to just non-recyclable resins.

Reviewer 2

The project is dedicated to developing a recyclable thermosetting resin system. Thermoforming chosen for the composite manufacturing process which is a thermoplastic composite manufacturing process may not be appropriate in this project. A complete and clear explanation of the selection of thermoforming manufacturing process thereby should be presented.

Reviewer 3

The proposed future works are demonstrated well. Particularly, the scale-up, and thermoforming of the vehicle part will play critical role for the success of the project.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The project supports the overall DOE objectives. It was shown in the TEA that in the second life of the CF would be less than $5 per kg, which is a sought-after goal within VTO to achieve more economical vehicle lightweighting.

Reviewer 2

The goal of the project is to develop materials and processing techniques for high-performance recyclable polymer composites, which is directly relevant to the VTO objectives.

Reviewer 3

This project clearly supports DOE objectives, especially, recyclable composite preparation from biobased feed stock reduces the cost of CF but also the carbon footprint.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The resources are sufficient to achieve the remaining milestones.

Reviewer 2

The funding amount is sufficient to develop the technologies.

Reviewer 3

The resources are sufficient for the project team to achieve the stated milestones in a timely fashion.

Presentation Number: mat210
Presentation Title: A Novel Manufacturing Process of Lightweight Automotive Seats - Integration of Additive Manufacturing and Reinforced Polymer Composite
Principal Investigator: Patrick Blanchard, Ford Motor Company

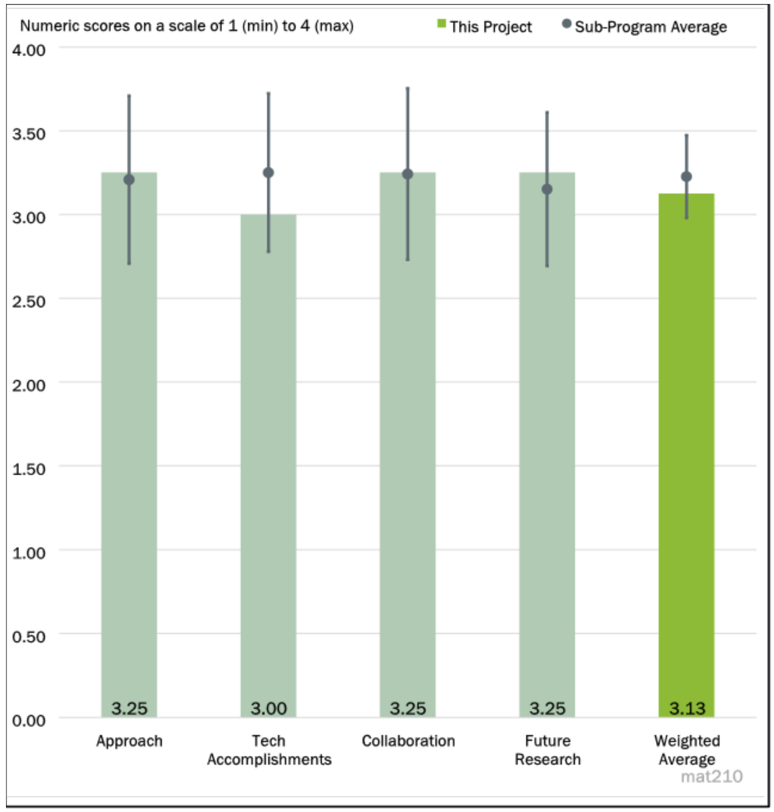

Figure 5-25 - Presentation Number: mat210 Presentation Title: A Novel Manufacturing Process of Lightweight Automotive Seats - Integration of Additive Manufacturing and Reinforced Polymer Composite Principal Investigator: Patrick Blanchard, Ford Motor Company

Presenter

Patrick Blanchard, Ford Motor Company

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The project team has identified and addressed the key technical barriers. The lightweight seat design was novel and the timeline is reasonable. The hybrid metal /composite seats are lightweighting and fuel saving.

Reviewer 2

The project team aimed to replace the metal frame with lightweight composites. The project was well designed even though the progress was not enough.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The project has accomplished the milestones as planned. The seat back reinforcement ribs panel is lighter and stronger. The digital image correlation (DIC) mechanical testing identifies high stress/strain concentration sites that in turn helps modify the design and printing.

Reviewer 2

The overall progress was satisfactory despite anticipation of more progress on milestones by the project team.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The collaboration between ORNL and Ford has been going well. The team works closely to optimize the design and processing which will help scale up and improve TRL

Reviewer 2

The project has good collaboration with the Ford Motor Company.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The proposed future research makes sense. The decision points for go/no-go are clear. The scaling plan is reasonable and achievable.

Reviewer 2

This is the final year for this project and so no future research was proposed.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The project supports the VTO overall objectives. The hybrid metal/composite seats provide weight savings and design and manufacturing flexibilities. This may be extended to other vehicle structures.

Reviewer 2

The project supports the DOE mission as they intended to develop efficient and sustainable transportation technologies.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

ORNL and Ford have the required resources for the project to achieve the stated milestones in a timely manner.

Reviewer 2

The resources were sufficient to achieve the stated milestones.

Presentation Number: mat211
Presentation Title: Sustainable Lightweight Intelligent Composites (SLIC) for Next-Generation Vehicles
Principal Investigator: Masato Mizuta, Newport Sensors, Inc.

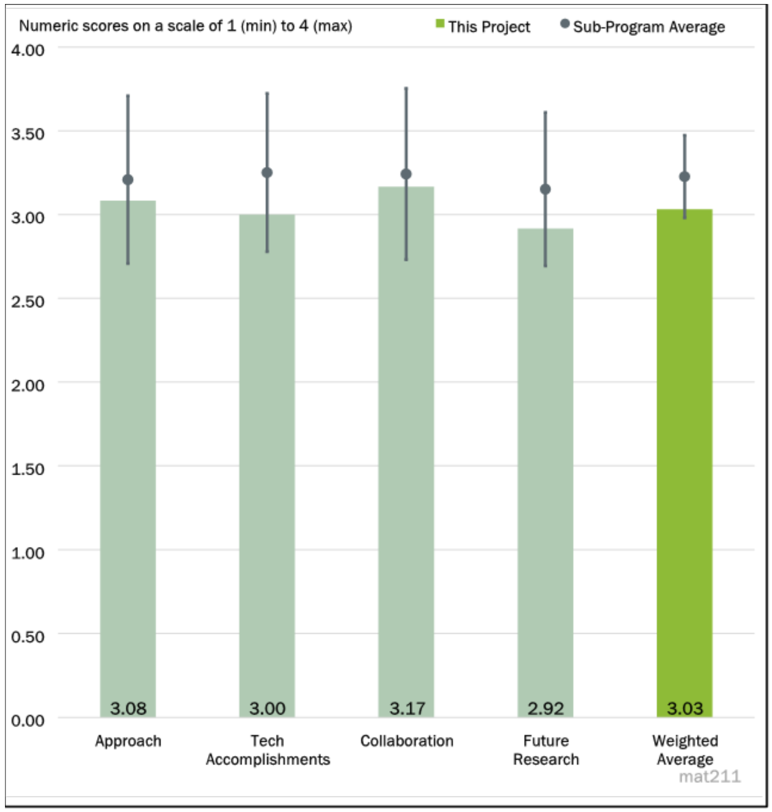

Figure 5-26 - Presentation Number: mat211 Presentation Title: Sustainable Lightweight Intelligent Composites (SLIC) for Next-Generation Vehicles Principal Investigator: Masato Mizuta, Newport Sensors, Inc.

Presenter

Masato Mizuta, Newport Sensors, Inc.

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The work appears to be on track with project timing plan with sufficient progress made on the sensor development. The gateways are clearly defined with quantifiable objectives.

Reviewer 2

The technical barriers were addressed and the project was well-planned. The project lacks novelty as the polyvinylidene fluoride (PVDF) use as a sensor on a composite may not be unique.

Reviewer 3

The approach is well designed to address the VTO requirement to develop a technology to detect damage in composite structures. This includes embedding static and dynamic sensor into a multi-component composite material that can be used in automobiles. The project is in the early stages of development; but the approach allows for scale up to actual automobile components. The ultimate sensing system would be capable of instantaneously detecting stimuli produced by an impact of a foreign object and sending a signal to the automobile onboard computer or to the owner’s cell phone. This system is applicable to the next-generation of transportation vehicles as was also evident in project’s title. This could be the first step towards developing a technology that could also facilitate the repair of damaged components.

Reviewer 4

The technology to detect damage in CF composites is identified in the referenced 2013 Workshop report as a Technology Gap along with methods to repair damage in CF composites. A comparative performance of the hybrid composite versus current commercial alternatives needs to be addressed for the combination of natural fiber and CF composites in the project claimed to increase crashworthiness and presumably thereby the high-cost issue of CF. The goal of 100% damage detection in CF composites is tied to the goal of reliable repair and the reduction in the overall cost of weight-saving CF composite by detecting and repairing defects to extend the useful lifetime of the composites. It would be good to include strain and impact sensors into a composite or as an adhered layer atop a composite part in this project clearly tied to weight and cost savings through enabling repairs and extending life. Onboard sensing circuits may add weight and adhering sensors onto composite surfaces may interfere with repair of defects.

Reviewer 5

The overall approach is well designed, and the work progress shown in the poster matches the project plans (milestones). The preliminary results show that integrated strain sensor detected the failure and even early signs of the failure. However, it is not clear what challenges (or technical barriers) the team had to overcome in order to achieve the current progress.

Reviewer 6

The approach involving both dynamic and static strain monitoring is theoretically a great idea. However, it is not clear why static strain monitoring is critical. As the dynamic load detecting system is based on PVDF layer applied as the middle layer of the composite structure, it is not clear whether it can be integrated within the whole structure, and subsequently in a scaled up designed part.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The ability of the sensors to detect substrate failure has shown the presence of microcracking after tensile testing. Use of the PVCF film appears to provide advance warning of failure when compared to DIC strain measurement methods.

Reviewer 2

All technical accomplishments have been met and the project remains on schedule. More technical accomplishments were anticipated for the commitment of a significant DOE cost share of the project. The quantitative criteria for the milestones should also be discussed to assess the success of the work.

Reviewer 3

The two-year project is new and work has been performed for only 10 months. Designs of the SLIC system have been initiated. Sample configurations for tensile testing and the test method (ASTM D3039) have been selected. Electronic components for amplifying the signals from the sensors were selected. The initial test setup was tested and successfully measured strain and detected micro cracks in the test samples and identified their location. This progress is very good for the start of this project. Concerns raised by the reviewers remain to be addressed in the next part of the project.

Reviewer 4

A reviewer comment on transitioning to sensors as a coating or layer helps to separate composite production and mechanical performance from sensing and does not create problem for the former with the latter. Strain and failure have been detected with applied sensors, but it is not clear how the detected signals might relate to phenomena experienced by an installed automotive composite part. Its strain history may enable prediction of fatigue-based lifetime limit. The PVDF piezo sensor was reported to detect microcracks 20 seconds before failure, the value of which depends on strain rate needs to be reported. It is likely that piezo-detected microcracks might be identified and repaired prior to complete failure and thereby save lifetime composite costs by enabling repairs by life extension. The tie to lowering costs of carbon-fiber enabled lightweight materials needs to be explicitly discussed.

Reviewer 5

The researchers manufactured CFRP composites with an embedded strain sensor. The sensor is described as a self-powered device by vibration, but the tensile test remains to be performed with vibration. It was not clear whether there were sensing issues (e.g., noise or insufficient power) when the power was provided from an external source for the test and for the self-powered case in the future.

Reviewer 6

The team successfully fabricated and tested specimens. The hypothesis has been tested using small specimens. The team needs to find out challenges with fabrication of large structures and testing.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

Collaboration across the project partners is shown in addition to roles and responsibilities.

Reviewer 2

A good collaboration between the University of North Texas was established including its role in the project was clear.

Reviewer 3

Collaboration and coordination necessary for only two performers of this project, i.e., Newport Sensors and Univ of North Texas is a minimal effort. The collaboration could be improved by involving a Tier 1 supplier of the materials that would have the sensors embedded and an automotive OEM for integrating the sensor system into body components.

Reviewer 4

North Texas production of the hybrid composite and Newport Sensors testing of sensors appear to be well coordinated. It is not clear about the involvement of Tier 1 or OEMs partners in this project and whether any OEMs will be interested in picking up the technology if the project is successful.

Reviewer 5

Composite manufacturing and testing are done by a collaborator (Univ. of North Texas). The sensor designing and manufacturing are done by the PI team (Newport Sensors).

Reviewer 6

The team involves University of North Texas that conducts fabrication and ASTM testing of specimens. The role of Newport Sensors was not clear and the intellectual property (IP) owner.

Question 4: Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1

Proposed work plan is satisfactory. However, it would be interesting to understand if the speed of response for the sensing technology could be used to initiate post-crash technologies such as air bag deployment. This would eliminate the need for supplemental sensors that are usually mounted to metallic substrates.

Reviewer 2

The future work is effectively planned in designing and fabricating a miniature bumper beam. More details should be discussed about the design of the electrical system that is needed to collect the signals. It would be good to know what electronics need to be added to the composite since this will add weight and complexity to the composite. More details should also be discussed about how the multifunctional composites will be fabricated in industry in terms of the level of necessary extensive electroding process and its feasibility to achieve in high volume production. A techno-economic analysis would be good to add in future work to assess the feasibility of commercialization.

Reviewer 3

The proposed future research is only for the remaining testing and designs to be performed in the second year of the project. Information is needed about the design approach and materials integration that will be needed for the miniature prototype component and the necessary research and development beyond testing the miniature prototype to transfer the technology to a Tier 1 supplier or to an automotive OEM.

Reviewer 4

It is necessary to consider the sensing function that forms the basis of this project in the fiber composite production. Composite samples for the purpose of only comparing the mechanical properties of the [sensor free] samples to plain CFRP baseline materials may not be meaningful. The scope of production goal to demonstrate novel natural fiber/CF composites with advantageous weight, crashworthiness, or cost, seem unconnected to the scope of monitoring and detecting composite damage. Similarly, production of a bumper from the hybrid material and putting a sensor on it seems like a combination of two different projects. It would be more appropriate to apply the sensor to a standard composite bumper with well characterized performance to evaluate the sensor and disconnect the natural fiber hybrid composite development from the sensor development.

Reviewer 5

The team plans to combine an energy-harvesting feature with the sensor system. As in the previous years, the energy-harvesting feature has already been developed in their earlier version of the sensor system, so the plan future plan seems achievable.

Reviewer 6

Additional details are necessary for the future research stated plan of completion of remaining specimen testing.

Question 5: Relevance: Does the project support the overall VTO subprogram objectives?

Reviewer 1

The sensing work is aligned to VTO’s mission of promoting lightweight materials technology for automotive applications.

Reviewer 2

This project is relevant to the overall DOE objectives as it focuses on vehicle lightweighting to reduce GHG emissions.

Reviewer 3

This project supports and is relevant to the overall VTO subprogram objective to develop technologies that rapidly detect damage after impact based on non-destructive evaluation approaches. This requirement is described in the Light Duty Vehicles Technical Requirements and Gaps for Lightweight and Propulsion Materials Report.

Reviewer 4

Hybrid composites have the potential to combine the contrasting performance and cost benefits of natural fiber composites with those of CF composites. This could help address objectives relating to the cost of liqhtweighting. Detecting damage in fiber reinforced composites is relevant to the goal of lowering the cost of lightweight composite materials if it can be tied to extending use lifetime through combination with repair technology. Detection of damage alone may make composite cars safer by alerting drivers to repair or replace before failure, but only saves costs if repair is more efficient than replacement.

Reviewer 5

The project is highly relevant to VTO objective, because the goal of this project is to develop materials for vehicle applications.

Reviewer 6

This is an important topic and relevant to VTO subprogram objectives.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

There appears to be sufficient resources to complete all outstanding tasks based upon the partner collaboration.

Reviewer 2

The resources are sufficient to achieve the remaining milestones.

Reviewer 3

The project funding is $1.1M for only two performers, i.e., a company and a university for 24 months. This funding level seems excessive to incorporate already developed sensors into existing composite materials and perform minimal laboratory tensile, bending, and impact testing.

Reviewer 4

Spending is behind schedule. Resources might be focused on commercial scale sensor development and connection with damage repair instead of production of and testing of composite coupons and bumper independent of the targeted sensors. Partnering with a Tier1, molder or OEM to obtain parts for testing with the sensors and development of strategy for sensor-enable repair decisions would be a good future plan.

Reviewer 5

The funding is sufficient. The project is in its 30% progress mark point for the $1.1 million in funding. With the budget so far, they developed two sensor systems and made polymer composites integrated with a strain sensor. Technical details of the sensors and challenges for composite manufacturing with the sensor need to be included in the presentation.

Reviewer 6

Total budget of $1.1 million appears excessive in comparison to the volume of work shown.

Presentation Number: mat212
Presentation Title: Integrated Self sufficient Structurally Integrated Multifunctional Sensors for Autonomous Vehicles
Principal Investigator: Amrita Kumar, Accelent Technologies, Sunnyvale

Presenter

Amrita Kumar, Accelent Technologies, Sunnyvale

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

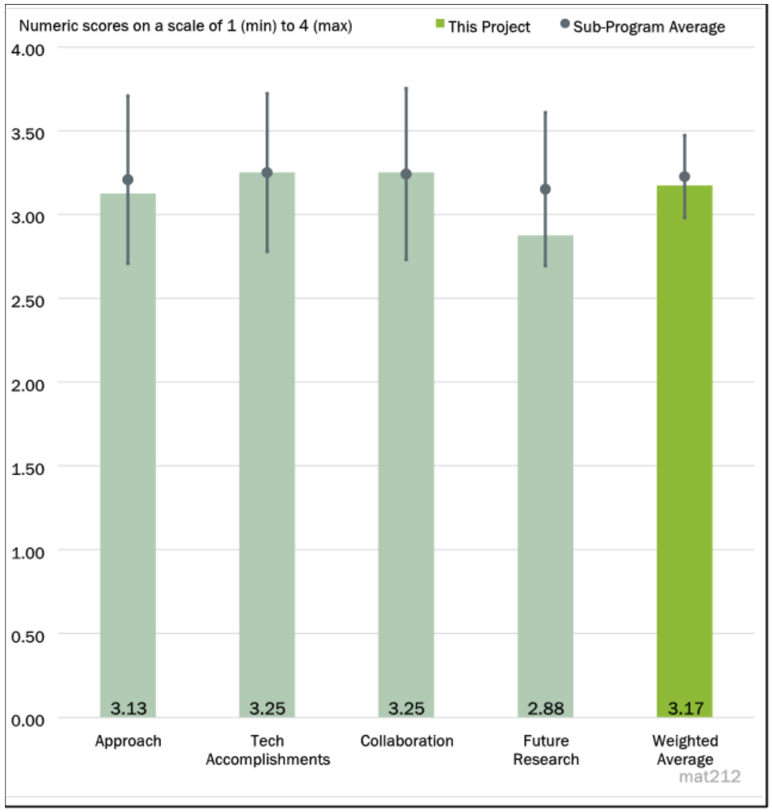

Figure 5-27 - Presentation Number: mat212 Presentation Title: Integrated Self sufficient Structurally Integrated Multifunctional Sensors for Autonomous Vehicles Principal Investigator: Amrita Kumar, Accelent Technologies, Sunnyvale

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The post application of sensor to components appears to be a viable approach. However, the cost of application remains a concern in addition to the durability of termination methods. It would be beneficial to understand what the total installation cost would be for such a system if implemented on the bumper beam as described.

Reviewer 2

The approach is to develop two monitoring systems, i.e., pedestrian impact with the front bumper and battery life, both of which would be integrated with the automobile's onboard computer system. These systems will provide functions beyond other systems and materials for load carrying of automobile structural components. The project is in its second phase and the plan is to work with an automobile OEM to test the monitoring systems in prototype components over the 2-year performance period. This approach is well designed to achieve the goals of testing prototypes, and the timeline is well planned to achieve these goals and provide the data that the OEM will need to accept the monitoring systems in future automobile designs.

Reviewer 3

The project purports to reduce weight and cost of vehicle composites by providing composite functionality in addition to load carrying. Reference is made to partner Stanford University ARPA-e fund work to develop structural composites that provide energy storage. Aerospace-focused technology in this project now will be extended to automotive composites in Phase 2. Such technology might save vehicle weight by incorporating energy storage into structural components thereby reducing the separate energy storage component requirement on the vehicle. The results and plans for the automotive composites applications effort need to be detailed in the poster and under the listed proposed future work items. The focus of this work on pedestrian contact detection and battery charge status monitoring needs to address also the DOE priority and industry technical barriers of material cost and manufacturing throughput to reduce fuel consumption and greenhouse gas emissions.

Reviewer 4

The team lays out a clear need for developing smart detection systems and two very applicable scenarios for detection systems relevant to batter applications. The approach has been described well by a description of their experiments with figures and data.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The team has made good progress in testing the sensor capability in a real-world application.

Reviewer 2

The project has been performing for only10 months. Sensors have been selected and sensor networks have been designed to be used in testing for the pedestrian protection system. A prototype plastic bumper from the OEM was received and sensors were installed. The test setup has been selected and algorithms were developed for detecting impacts and preliminary tests were conducted. Development of the battery monitoring system was initiated and tests are being designed in collaboration with Stanford University. Progress is in accordance with the plans outlined in the Approach and is outstanding for the short period of performance.

Reviewer 3

Sensor response to artificial leg versus response to weight were characterized toward discriminating pedestrian impact from non-pedestrian impact. Considering the variety of ways that a human might present to a vehicle during impact, it is difficult to believe that the nature of the piezo sensor response will be able to discriminate human vs non-human impact in a meaningful way. It is not clear how success in this effort and by Standford University partners will increase use of weight-reducing composites in vehicles. Stanford University partners monitored the charge characteristics of a battery with an attached piezo sensor.

Reviewer 4

The project team has acquired and built a wonderful testing setup for this work and are developing methods to speed up sensor response time. All tools seem to be in place for future success.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The presentation shows a clear collaboration with the OEM leading to experimental verification of the technology under development.

Reviewer 2

The team consists of a Tier 1 supplier, an automotive OEM (Ford), and an academic institution (Stanford University). Collaboration and coordination appear well developed and continuous for the development and testing of the systems. It is appropriate to have an OEM involved in the component tests and a university involved in the battery health monitoring system concept. Addition of a National Laboratory with experience in automotive systems as a consulting collaborator would possibly minimize any risks in the design and testing of the system.

Reviewer 3

Collaboration with technology-provider Stanford University and OEM Ford strengthen the project team and a case for interest in the project outcomes. An additional key partner such as part fabricator or Tier1 supplier for the implementation of the developed technology would be useful.

Reviewer 4

The collaborations are established, including relevant IP rights, and have resulted in the procurement of bumpers for their testing. It seems that work with collaborators is yet to be started.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The proposed work plan is clearly defined and will allow a complete technical and commercial evaluation of the technology at the conclusion of the project.

Reviewer 2

The slide on future research should also address the research beyond the current project besides what will be done for the remainder of the project. Completion of a pedestrian protection system and a battery monitoring system are expected deliverables, although the pedestrian system is a second level of sensing and warning that complements technologies for collision warning systems in currently produced automobiles. Commercialization plans and cost targets is a great final deliverable for this project. Development of a unified multifunctional sensing system for cars could possibly be research required beyond the current project but details are necessary.

Reviewer 3

The future work addresses well to include the consideration of commercialization plans and cost estimates. However, the mentioned part of the project that directly addresses DOE technical barriers of cost/weight reduction, development of integrated structural/energy storage composites, needs to be mentioned in the proposed Future Work. On the other hand, current focus remains for future work on pedestrian detection and battery charge monitoring. A clear connection needs to be made between these goals and achieving DOE targets for reduced energy usage and emissions from lightweighting.

Reviewer 4

Some of the ongoing work seems to be a part of the future work, but multi sensing integration is very relevant future work. It might be good to understand the alternative options of the current detection, if there are any, and how that may inform future work.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The technology under development promises to be a key enabler to using lightweight composite components in future vehicle applications.

Reviewer 2

This project supports the overall VTO subprogram objective to provide functions beyond other systems for monitoring of structural automobile components as described in the Light-Duty Vehicles Technical Requirements and Gaps report.

Reviewer 3

The project tangentially supports weight reduction through potential combination of energy storage and structural function, but the primary focus elements of making autonomous vehicles safer and battery maintenance more efficient may not be directly relevant to lightweight material goals.

Reviewer 4

The project seems aligned both with the sup program and has implications to other programs, such as detection in batter systems.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

An excellent team leading the project by leveraging their own resources but also receiving OEM guidance on the relevance of the technology. Available resources should be sufficient to make a final evaluation on the technology viability.

Reviewer 2

The $1.14 million of DOE funding over 2 years is sufficient for the three collaborating activities to develop the two systems described in the presentation. The performer, the original equipment manufacturer (OEM, and the university have sufficient resources to complete the design and testing of both systems.

Reviewer 3

The project appears underspent and the majority of budget is still available.

Reviewer 4

The project appears to be on track with adequate resources.

Presentation Number: mat215
Presentation Title: Short Fiber Preform Technology for Automotive Part Production
Principal Investigator: Dirk Heider, Composites Automation, LLC

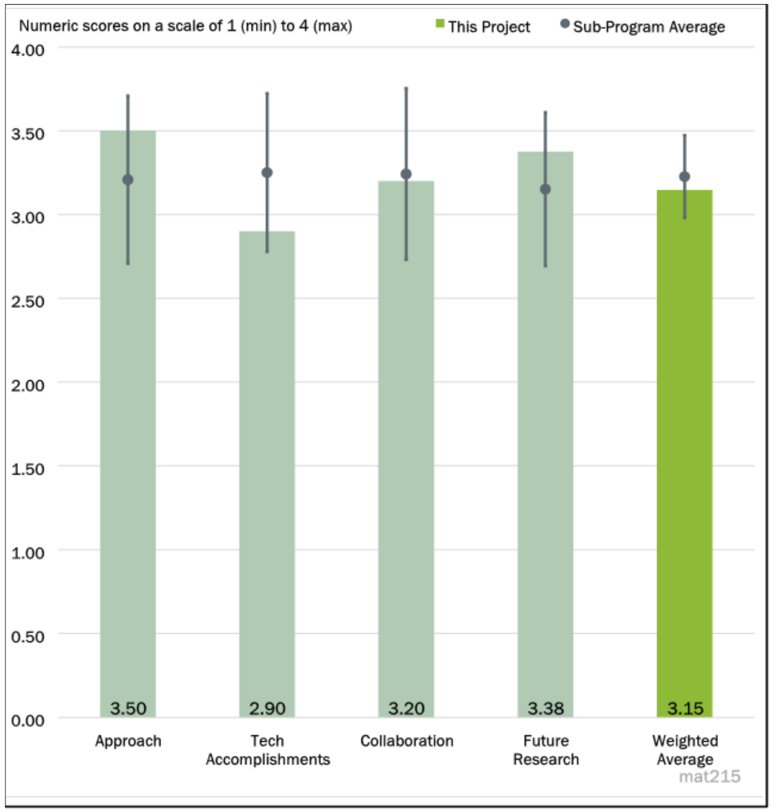

Figure 5-28 - Presentation Number: mat215 Presentation Title: Short Fiber Preform Technology for Automotive Part Production Principal Investigator: Dirk Heider, Composites Automation, LLC

Presenter

Dirk Heider, Composites Automation, LLC

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This project is clearly focused on development of high throughput, cost saving techniques for high performance carbon fiber composite production, including those capable of incorporating recycled fiber. This focus addresses DOE and industry technical barriers of material cost and manufacturing throughput for carbon fiber composites.

Reviewer 2

This reviewer stated that the use of recycled/waster carbon fibers hybrid with glass fibers is excellent. That approach addresses the needs of sustainability as well as cost competitiveness.

Reviewer 3

According to this reviewer, the poster was not presented in a way that made it easy to ascertain information on the process or project. The reviewer intimated that the poster was more like a set of PowerPoint slides put together in random order rather than a cohesive presentation. The reviewer further stated that while this comment may not seem applicable to the approach of the work, it applies to all the questions included in the review.

The reviewer believed that the presentation had omitted too much information to enable actually understanding the process and how the PIs are achieving the target performance. That being said, the reviewer stated that the modulus of their materials is impressive and that the wet compression approach seems to result in the best properties. The poster showed a lack of definition regarding cycle time, which is one of the project's main goals. The reviewer indicated that this section is scored higher as the overall approach to work in using waste or recycled fibers is strong.

Reviewer 4

According to this reviewer, the processing methodology for incorporation of recycled carbon fiber reinforcements promises to provide a lower cost preforming option. The reviewer stated, however, that it is not clear how much shape complexity can be achieved with this material format, particularly when considering out-of-plane features such as ribs.

Reviewer 5

The technical barriers are addressed well but the overall configuration of the slides is very confusing. The slide numbers are not in order. The slide number should increase like 1, 2, 3, …, final slide. Instead, the slide number changes as 1, 12, 11, 10, 9, 8, …, 2. Also, the font is blurry and the pictures are in low resolutions.

*Question 2: **Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.***

Reviewer 1

This reviewer stated that, while the poster presentation was not perfectly clear, the project team seems to be accomplishing excellent performance and moving into commercialization trials.

Reviewer 2

This reviewer found that the team made progress on validating some of the scalability issues. However, the reviewer believed that it is not clear whether a significant advantage over existing commercially available short fiber products such as a carbon fiber based sheet molding compound would remain after scaling. The reviewer stated that there is also no mention of lass transition temperature (T_g), which could be a barrier depending upon where parts are installed during the assembly process (i.e. body shop versus trim and final).

Reviewer 3

This reviewer referenced prior comments and said that too many data have been omitted or not provided in a digestible way to assess performance. It was apparent that the tailorable universal feedstock for forming (TuFF) process results in robust composites, but as the goal of the work is to reduce cost or time, some of that data needs to be provided.

Reviewer 4

This reviewer stated that the project plan and accomplishments are difficult to ascertain from the submitted poster as it is an image consisting of several slides copied and pasted from another presentation in apparent random order to create a poster. The reviewer noted that slides are numbered, but not in the order in which they are shown and some slide numbers are missing.

The reviewer believed that the plan for the recent period was apparently to produce material for testing and to create a full database of properties as well as to work on commercialization. The reviewer does not see any report of progress on production, testing, or commercialization. The reviewer mentioned that these activities were undertaken, but one does not find them reflected in the chaotic poster.

Reviewer 5

This reviewer stated that the slide contents are the same as last year's slides, indicating that the progress over this year has been minimal. For example, according to the reviewer the work involving fabrication of TuFF preforms with different fibers is shown in this year's presentation as it wash in last year's presentation; mechanical performance of waste fiber composite is shown in this year's presentation, and the same result was shown in last year's presentation; complex geometry TuFF forming demonstration is shown in this year's presentation, and the same demo was shown in last year's presentation; The close-up photos showing complex features in this year's presentation are the same as in last year's presentation. Because of this, the reviewer could not identify the new developments and progress in the project.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer found that collaboration appears a strength of this project, between small business technology provider, university, OEM, resin and fiber suppliers, and industry groups.

Reviewer 2

This reviewer stated that the team's collaboration is excellent, which sets a path for commercialization.

Reviewer 3

This reviewer said that collaboration across the partners has been clearly demonstrated.

Reviewer 4

This reviewer, while noting that Composites Automation is leading the project, partnered with the University of Delaware, the role of each organization is not clear.

Reviewer 5

According to this reviewer, the project team has collaborators listed, but it is not clear who does what or how that has led to success in various components of the project.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the project is ending in a couple of months and that the team has achieved most of the original targets and explained plans for the remaining effort.

Reviewer 2

This reviewer concluded that the plan of hybrid layups and the proposed demonstration seems to be work worth pursuing.

Reviewer 3

This reviewer concluded that the team has completed most of the project and that its future plan is good.

Reviewer 4

This reviewer noted that the remaining portion of work is well defined, although automotive applications may be limited due to the shell style construction of molded parts because efficient designs in composites usually incorporate ribbing and other features that can be molded to enhance section stiffness. The reviewer believed that this does not appear to be easily achieved using the TuFF materials.

Reviewer 5

This reviewer has not found a Future Work section in the materials provided, stating that the project period appeared to end at August 2022, while the Phase2 proposal was submitted in April 2022.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer stated that the technology is aligned with VTO's mission for the development of lightweight materials for automotive applications

Reviewer 2

This reviewer noted that the project focuses on the primary priorities of the VTO Lightweight Materials Subprogram: reducing the cost of carbon fiber composite materials and of production methods and increasing production throughput.

Reviewer 3

The reviewer said that the team developed a composite manufacturing technique for recycled and waste fibers, which is highly relevant to the VTO Materials program.

Reviewer 4

This reviewer stated that the re-use of fibers, especially those that might not immediately maintain their orientation, is highly interesting and necessary for the field at large.

Reviewer 5

This reviewer stated that the project is highly relevant to VTO.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

Sufficient resources have been deployed which have since led to the submission of a follow up Phase IIB application.

Reviewer 2

The reviewer stated that the project appears to have concluded.

Reviewer 3

This reviewer believed that the resources are sufficient for the project.

Reviewer 4

This reviewer assessed that the project is progressing at a reasonable pace with adequate resources.

Reviewer 5

This reviewer said that the resource are sufficient.

Presentation Number: mat216
Presentation Title: Low Cost Resin Technology for the Rapid Manufacture of High-Performance Fiber Reinforced Composites
Principal Investigator: Henry Sodano, Trimer Technologies, LLC

Presenter

Henry Sodano, Trimer Technologies, LLC

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

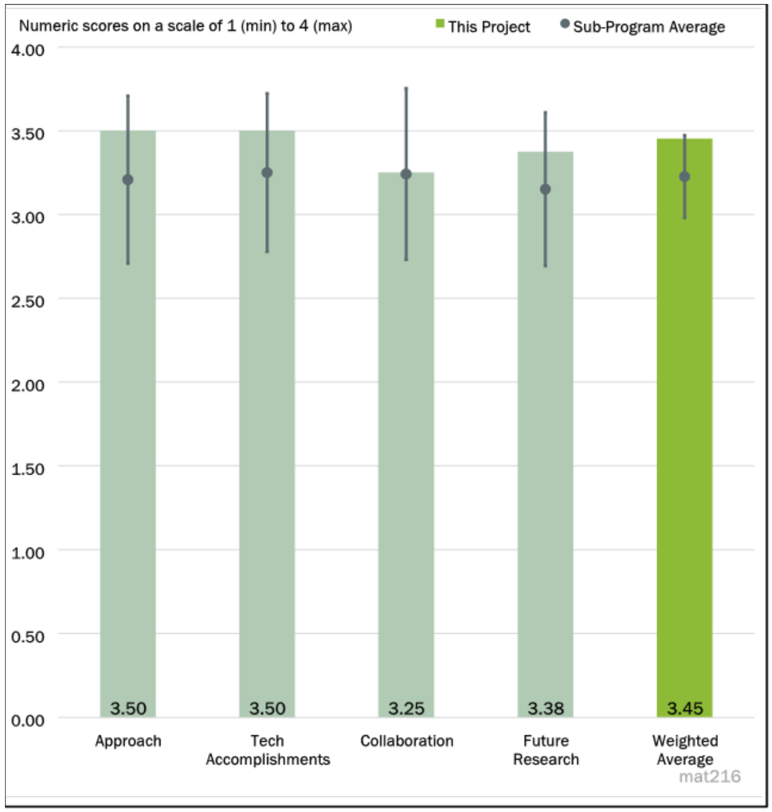

Figure 5-29 - Presentation Number: mat216 Presentation Title: Low Cost Resin Technology for the Rapid Manufacture of High-Performance Fiber Reinforced Composites Principal Investigator: Henry Sodano, Trimer Technologies, LLC

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer stated that this project focuses on development of a high performance resin for carbon fiber composites that has a very rapid cure time to facilitate high throughput production of carbon fiber composite parts. It includes comparisons with relevant baseline resins and evaluates many important cure and performance characteristics. The project work is being performed through partnerships with an industry group, a molder and an OEM. and are evaluated.

This reviewer stated that the only thing not seen to be addressed is the anticipated cost and availability of the novel resin. The reviewer questions whether its appealing performance will be cost prohibitive to make an impact on DOE goals, even with rapid cycle time?

Reviewer 2

This reviewer noted that the team has thermoset resin that can provide a fast cycle time via rapid curing chemical kinetics. Using the resin, the team manufactured composite panels and performed mechanical tests as well as environment tests. He judges the project to be well designed.

Reviewer 3

This reviewer found that the work seems very strong in that the team has developed a low cost, fast cure resin that results in robust composites. The amount of material property testing performed, with the team's systems is impressive . The reviewer found it hard to assess the team's approach as the presentation did not disclose any information about the resin's or composites 'chemistries, only that it meets the target specifications. As different resins have concerns with safety the chemical information should have been provided. Moreover, there may be other benefits from the chemistry. In one section the results were compared to Crestapol, a urethane acrylate, which has ester linkages, suggesting possible recyclability. Additionally, the chemistry often informs the approach, making it useful for evaluating it.

Reviewer 4

This reviewer stated that, while the detail has not been disclosed, the trimer yields rapid cure thermoset resins with high mechanical performance, along with flame retardancy. He states that the approach is promising, and will meet various needs of composite materials.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer said the amount of testing and demonstration of fast cures is simply impressive. The reviewer said prior comments about a lack of chemical detail is still valid; however, the data provides clarity.

Reviewer 2

This reviewer found that the team's thermoset resins allow rapid cure, with mechanical performance as high as 105 MPa tensile strength, which is very good. The tensile strain is 4%, which indicates that their brittleness is handleable. It also shows flame retardancy without additional additives. This technology shows promise and can address some needs in vehicle applications.

Reviewer 3

This reviewer stated that the poster is 90% identical to the poster shown at the 2021 VTO AMR, with the differences being the addition of Ford as a partner, production at Institute for Advanced Composites Manufacturing Innovation (IACMI)- Scale-Up Research Facility, and achievement of faster cure time. The demonstration of thirty seconds improvement in thick part curing from 120 seconds to 90 seconds is impressive and good progress.

Reviewer 4

This reviewer said that the team showed high mechanical performance results of the composite made with its resin as compared to another fast curing resin. The reviewer said that the team claimed that its composites have higher performance than composites with an aerospace resin (Hexcel 8552), but those data are not shown in the presentation. The reviewer said that the major issue of this presentation is that it showed no progress or difference from the last year's presentation. According to the reviewer, all the results and figures and data in this year's presentation are the same as those in last year's presentation.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer states that the collaboration with a molder, an OEM, and the composite industry incubator well position the development resin technology for commercialization.

Reviewer 2

This reviewer noted that the team has various collaborators for the application of this technology.

Reviewer 3

This reviewer noted that the team listed IACMI, Ford, and TOP as partners, but finds the roles of the partners to be not clear.

Reviewer 4

This reviewer noted that there are collaborators in place but the division of work is not apparent.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the proposed investigation of resin scale up and component level testing is clearly relevant and necessary for understanding cost and commercialization potential and for attracting commercial partners.

Reviewer 2

This reviewer found that the component testing and resin scale up is needed but that it is hard to comment on the scalability of the resin with no details about its chemistry (even its material class)._

Reviewer 3

This project is almost at the end. With the current data, the team have a promising path for commercialization.

Reviewer 4

This reviewer pointed out that the time remaining until the project end date is limited, but the future plans do not require significant efforts. Therefore, the team will likely accomplish the plans.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer states that slow curing has been a persistent barrier for carbon fiber composites for vehicle applications. Development of a high performance, rapid curing resin for fiber reinforced automotive components directly supports VTO lightweight material subprogram objectives for enabling increased use of weight-saving carbon composites on vehicles.

Reviewer 2

This project utilizes a fast curing resin for short cycle time in composite manufacturing. Therefore, it aligns well with the VTO material subprogram’s objectives.

Reviewer 3

The work focuses on making robust lightweight materials with short cycle time and thus is highly aligned with office goals.

Reviewer 4

This is highly relevant technology for VTO.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer states that milestones of sufficient mechanical performance and reduced cure time have been met but proposed future work, including scale up and component level testing, may require additional funding and time beyond this project, which ends 8/2022.

Reviewer 2

This reviewer says that the funding is sufficient for the project.

Reviewer 3

This reviewer says that the team has made fantastic progress with the current budget.

Reviewer 4

This reviewer says that the resources are sufficient.

Presentation Number: mat221
Presentation Title: Lightweight and Highly-Efficient Engines Through Al and Si Alloying of Martensitic Materials
Principal Investigator: Dean Pierce, Oak Ridge National Laboratory

Presenter

Dean Pierce, ORNL

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

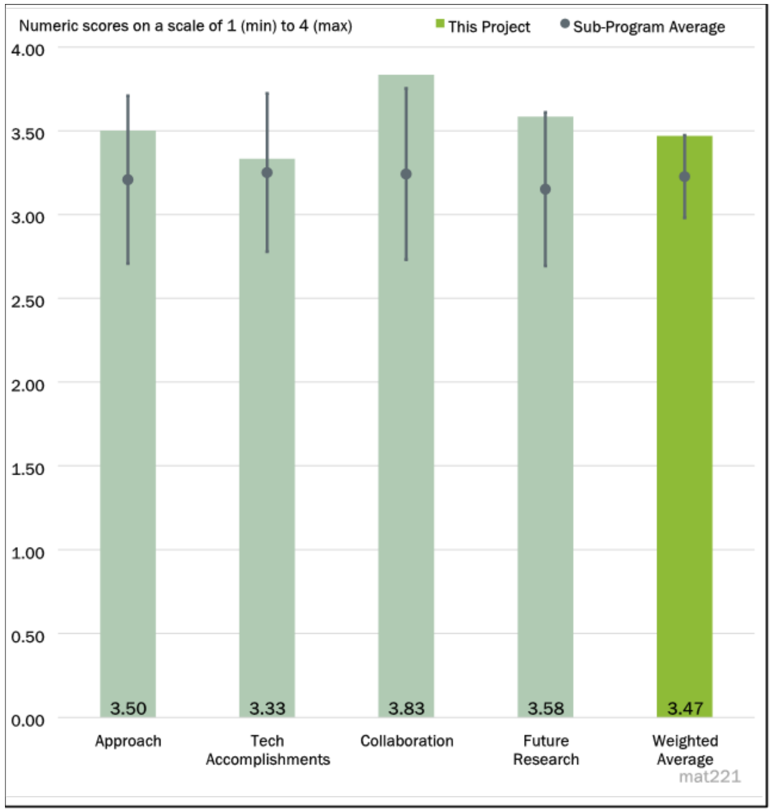

Figure 5-30 - Presentation Number: mat221 Presentation Title: Lightweight and Highly-Efficient Engines Through Al and Si Alloying of Martensitic Materials Principal Investigator: Dean Pierce, Oak Ridge National Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

This reviewer found the presentation gave a clear description of the challenge with the trade-off between mechanical and thermal properties. Integrated computational materials engineering (ICME) design of alloys is a real strength of this project.

Reviewer 2

This reviewer notes that the project has considered the development of new higher-temperature alloys at lab-scale in the first 2 years, with the focus shifting to scaling up the alloy processing and manufacturing of prototype pistons for engine testing in the third and fourth years. Entering the final year, the project has seen significant progress in the scale- up activities and is now focusing on manufacturing prototype pistons with industry partners. The reviewer believes that many technical barriers have already been overcome and remaining challenges are well addressed, with a reasonable timeline for the manufacturing and engine testing planned for the final year. The reviewer pointed out that there was no discussion of tests of the oxidation resistance of the scaled-up alloy in the future plans described in the slides, but it was mentioned verbally that these will be undertaken. Such oxidation tests, according to the reviewer are viewed to be an important addition to the planned work.

Reviewer 3

This reviewer stated that the overall effort leverages the concepts of computational materials design with good old-fashioned physical metallurgy for a specific need within ICE.

Reviewer 4

This reviewer believes that working to improve the efficiency of HD vehicles is paramount in lowering carbon emissions in the short term, as there is no current strategic consensus on how to move freight using battery electric vehicles. Other types of propulsion systems require infrastructure that is not present or easily available. So, the reviewer believes that this offers a real opportunity to improve the environment.

Reviewer 5

This reviewer states that the scope and approach for the planned work has been well laid out. There are several technical barriers such as the machinability/weldability, creep, corrosion performance and cost of the alloys. Some of the results were not reported, so the reviewer believes that it is difficult to make a judgement as to whether the technical barriers have been fully addressed or not. In terms of progress, the most promising alloy has been down selected and has been fabricated at high temperatures. The alloy is yet to be tested in an engine environment. The other challenge that needs to be addressed is the manufacturing of the piston prototypes.

Reviewer 6

Slide 2: This reviewer believes that the key barrier to the subject technology is thermal fatigue at the sharp corner of the bowl rim, which is not mentioned in the presentation. This is the specific reason why steel is used. The project needs to include testing for thermal fatigue with samples that have sharp corners.

Regarding Slide 8, the reviewer understands that the authors do not wish to disclose the alloy compositions. However, the approach for alloy development should be mentioned considering 35 alloy chemistries were made. What are some of the alloying elements used and ranges etc. The reviewer asked was this a design of experiments of some sort with some prior knowledge of effects of the alloying elements.

*Question 2: **Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.***

Reviewer 1

This reviewer observed that the ability to create in-cylinder components that can allow further increases of cylinder pressures and higher cylinder temperatures has been shown clearly to be a lever to decrease emissions and increase power density. The reviewer states that this project offers the next logical extension to this process by enabling the move even further up in both these critical parameters.

Reviewer 2

This reviewer found that the team had made excellent progress including the identification of an alloy for scaleup in the first 2 years leading to a worldwide patent application submission. The reviewer anticipates successful scale-up in year 3, with initial steps completed towards piston manufacturing, which will be continued in the final year.

Reviewer 3

This reviewer found that, overall, the progress has been excellent and 75% of the work is complete. However, as the reviewer discussed above, a couple of key items on the engine testing and manufacturing aspects for pistons remain to be completed. Several project activities listed need to be completed by April 2023, which the reviewer believed could be a bit challenging.

Reviewer 4

This reviewer believed that upscaling of the down-selected alloy is very exciting. Fatigue life is very encouraging. However, even if the actual thermal conductivity values cannot be shown, it is important to at least discuss them or show data without numbers as was done with fatigue life, since a major point was made of the tradeoff between mechanical and thermal properties. It would be good to show the FEA predictions of how the new alloy will perform. Oxidation testing of the scaled-up alloy would be very important.

Reviewer 5

The reviewer said regarding Slide 11, the need to not disclose any details makes it difficult to determine the extent of actual improvement. The reviewer also pointed out that only six fatigue data points are shown and asks if the fatigue samples are polished and what the fatigue initiation sites for the three that failed are. The reviewer asked whether some Alloy 4140 and micro-alloyed steel (MAS) data could be added to put the alloy data in perspective.

The reviewer found the data and information provided to be sparse considering that the project started in 2019, asking if there has been any microstructural work.

Reviewer 6

This reviewer found the technical accomplishments thus far to be considerable in terms of showing promise but without really demonstrating success against defined targets. The reviewer questions why program milestones cannot be released, saying that it makes the evaluation of program progress considerably more difficult. According to the reviewer, alloy 4140, for its part, is not an overly exotic alloy or even an exotic steel. The reviewer concludes that cost is clearly a strong consideration, which is why more capable and proven alloys are not already being utilized. He states that clarifying the effort relative to the present limitations of the state-of-the-art (even if qualitatively) would be helpful.

The reviewer notes that Slide 11 shows exceptional fatigue strength, but no baseline fatigue value (or even a direct comparison with Alloy 4140 within the 4140 operating range) is provided.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer states that the team has developed a productive collaboration between ORNL, Cummins and Mahle, with clear delineation of the synergistic tasks to be led by each partner being well identified.

Reviewer 2

This reviewer says that the team at ORNL has clearly been working with a large team at Cummins, and this collaboration increases the opportunity for innovation and novel solutions.

Reviewer 3

This reviewer notes that the effort has been divided among the partners based on their expertise and capabilities. Alloy production has been completed at the national lab and now the characterizations/manufacturing/engine testing will be conducted at the industry partners. Based on the progress so far, the project team has been functioning well in their roles.

Reviewer 4

This reviewer found a good balance of work across lab and industry partners (Cummins and Mahle).

Reviewer 5

This reviewer believed that the involvement of both Cummins and Mahle is an excellent reflection on the efforts of the proposal group to build a strong team with a significant industrial component.

Reviewer 6

This reviewer says that the collaborators are well engaged, based on Slides10 and 15.

Question 4: Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1

This reviewer anticipated that bringing Mahle on-board with the team will further increase the team's knowledge and capability, and this will offer greater opportunities for a true commercial success from this important research.

Reviewer 2

This reviewer said that the future work and its purpose for achieving the goals of the project are well defined. Excellent progress made in scale-up and initial steps toward manufacturing suggest that the team is likely to achieve the remaining targets in the final year.

Reviewer 3

This reviewer opined that if manufacturing and testing are the largest remaining barriers to relatively short-term success, then the project overall has done well. The other more obvious barriers have been overcome.

Reviewer 4

This reviewer pointed out that future work is clearly outlined and is mostly development focused but asks if any modeling will be done?

Reviewer 5

This reviewer noted that future work will focus on the manufacturing of prototypes for engine testing and that the details on these activities were quite limited in the presentation, perhaps, due to IP related concerns. Nevertheless, future effort will primarily be carried out by the industry partners who have significant experience in the area, and risks for completion of the work are low.

Reviewer 6

This reviewer says that the future work seems reasonable.

Question 5: Relevance: Does the project support the overall VTO subprogram objectives?

Reviewer 1

This reviewer found that the project supports the objectives in the Propulsion Materials portfolio associated with enabling increased operating temperature and engine efficiencies in HD diesel engines. It advancing these goals through an alloy design effort that is responding to specific requirements that include increased high-temperature strength, fatigue and oxidation resistance.

Reviewer 2

This reviewer said that the work is clearly an immediate need and has potential to provide the type of benefit the DOE seeks with VTO efforts. The bridge between electrification and the short and intermediate term needs of heavy transportation is nicely defined.

Reviewer 3

This reviewer found the project to be clearly aligned with Energy Efficient Mobility Systems, and should contribute to the successes in that program.

Reviewer 4

This reviewer stated that the project well supports a class of engines that will continue to rely on internal combustion for some time into the future.

Reviewer 5

This reviewer stated that there are challenges with electrification of heavy duty vehicles and ICEs are still the most viable option. Development of new engine high temperature alloys will allow for increased engine temperatures/pressures and fuel efficiency. In this regard, the project is well aligned with the VTO's Materials technology program objectives.

Reviewer 6

This reviewer believed that the work is very relevant, due to the difficulty of electrifying long range transport vehicles.

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

Reviewer 1

This reviewer pointed out that Mahle has been brought in as a partner for the manufacturing efforts, enhancing the resources of the project.

Reviewer 2

This reviewer noted that the resources are bolstered considerably by the impressive industrial cost share.

Reviewer 3

This reviewer believed that the project seems to be well resourced and is well represented by their accomplishments and planning, including a clear focus on future work

Reviewer 4

This reviewer found that the resources appear adequate for the project.

Reviewer 5

This reviewer pointed out that the project is a Lightweight Materials Consortium (LightMAT) project with industry partners. Cummins and Mahle. The effort and the resources are available amongst all the partners for successful completion of the project milestones.

Reviewer 6

This reviewer said that the resources provided are reasonable for the proposed work.

Presentation Number: mat222
Presentation Title: Extending Ultrasonic Welding Techniques to New Material Pairs
Principal Investigator: Jian Chen, Oak Ridge National Laboratory

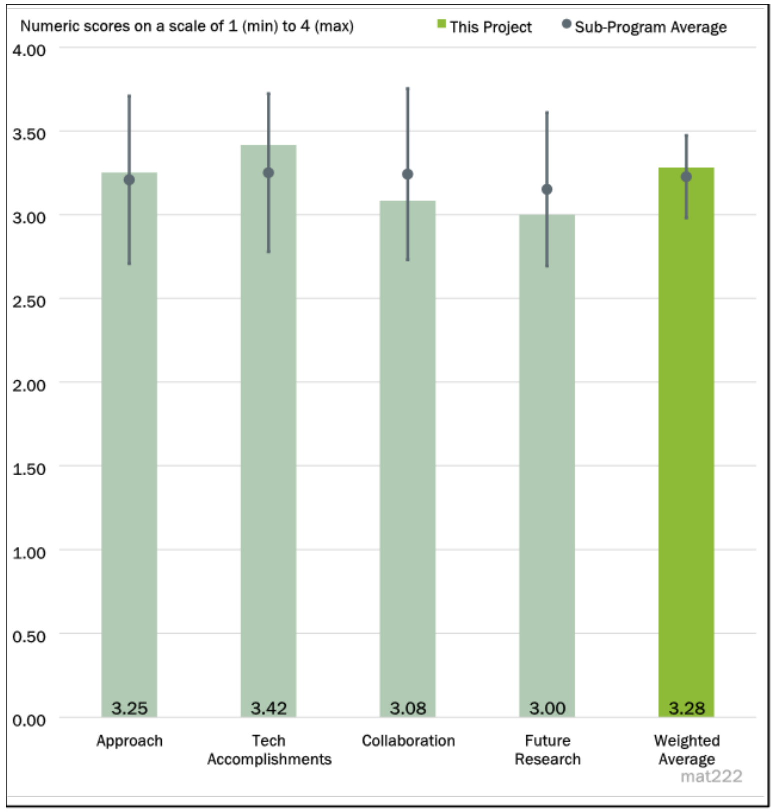

Figure 5-31 - Presentation Number: mat222 Presentation Title: Extending Ultrasonic Welding Techniques to New Material Pairs Principal Investigator: Jian Chen, Oak Ridge National Laboratory

Presenter

Jian Chen, ORNL

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that the project objectives and timeline are reasonably planned, and the team is on track. The project plan addresses major challenges to multi-material joining.

Reviewer 2

This reviewer said that Jian Chen is doing a good job and that the program is well defined with real life applications.

Reviewer 3

This reviewer stated that the project approach seems novel as past attempts with conventional approaches have been unsuccessful to ultrasonically weld large parts. This project used a model-based engineering strategy to guide the development of a new process using multi-scale modeling, ultrasonic joining processes, in-site measurements, and post-weld characterization.

Reviewer 4

This reviewer stated simply that the project attempts a model based engineering approach to extend ultrasonic welding to new pairs of materials like Mg and steel.

Reviewer 5

This reviewer stated that the project is investigating important joining processes to examine multi-material joining. However, the go/no go structure is a bit confusing as the tasks don't appear to really build upon each other. They actually seem like three very separate tasks. For example, the reviewer stated that it is not really clear how the Mg-steel joint development, which had to utilize adhesive, really influenced the multi-joint development of the Mg-Al and Al-steel Ultrasonic spot welding (USW) joints. That said, the tasks have all appeared to generate or be likely in future to generate valuable information.

Reviewer 6

This reviewer reported being a little unclear on the barriers being addressed by the project. According to the reviewer, Slide 5 says that "past attempts with conventional approaches are unsuccessful to ultrasonically welding large components." The reviewer suggested that, perhaps some more background on what is "conventional" and is meant by unsuccessful would be useful; The reviewer asked what is the problem that caused earlier efforts to fail to join dissimilar materials.

The reviewer also expressed confusion over the observation that, when joining materials with multiple spots along a joint line, what the joint strength varies with , whether position .or proximity to the coupon edge. In either case, the reviewer asks whether this occurs both with joints between similar and dissimilar materials? The reviewer opines that the approach would have been clearer if the problem being addressed was better defined.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer stated that the joining of Mg-steel components was accomplished, with consideration to the associated corrosion challenges. The team was able to achieve their target peak lap shear loads. One of the major challenges of the project was inconsistent heat generation during USW at different locations, and the team was able to replicate and resolve this challenge in the model by varying welding energy based on location. This was a significant accomplishment, as multi-joint coupons were able to perform as well as single-joint coupons in terms of peak lap shear load. Collectively, these (among other) accomplishments have kept the team on track relative to the project plan. The next milestone will involve similar work on component-level structures, and there are no current "red flags" to indicate that the team will not be able to complete it. The modeling appears to be strong, and it will be a powerful tool moving into the upcoming milestone with more complex geometries.

Reviewer 2

This reviewer believes that the team has followed a good technical process and that it was a good idea to create MAT225 because I think that corrosion has been a distraction for this program toward target goals.

Reviewer 3

This reviewer says that the project has had several significant accomplishments, including single-joint USW coupons with different welding conditions, quantification of galvanic attack on Mg, and a preliminary corrosion mitigation approach. In-situ measurements and post-weld characterizations showed the difficulty in joining multi-joint large coupons. A new model-based approach was developed to determine process parameters for welding large coupons which resulted in consistent joint quality. Additionally, USW was applied to Mg-Al and Al-steel coupons based on insights from numerical modeling and experimental trials.

Reviewer 4

The tam showed excellent progress in joining immiscible elements (Mg and iron [Fe]) and also extended USW to Al-Mg and Al-steel pairs. Galvanic corrosion was also addressed in the activities.

Reviewer 5

This reviewer stated that the project achieved its goals of making joints in large Mg-steel components, although having to utilize adhesive did appear to set back the original goal of not using a third material for joining. The adhesive was used for corrosion mitigation but the reviewer questions whether it also contributes to the lap shear strength. The presenter indicated that the USW parameters could be tuned to consistently give a higher lap shear strength; the reviewer questions whether that due to a change in the failure mechanism itself (e.g. button pullout versus delamination). Also, the multi-weld joint simulation and experimental work showed required changes in process parameters to generate a good weld. While agreeing that lap shear strength is a good destructive measurement tool, the reviewer asks whether the simulation is really predicting button size of the weld. The reviewer believed that either that or some other non-destructive metric would be a better output in order for this model to be used for production parts, , not being sure that there a correlation.

Reviewer 6

This reviewer opined that the observation that samples with the highest lap shear strength were made at the highest weld temperatures was interesting and a good use of in situ thermal imaging. The fact that the welds closest to the coupon edge were the hottest (reduced thermal mass) is probably not surprising and the conclusion that welds made in the center of the coupon need more energy to reach some critical temperature also follows well, even without modeling. But the reviewer believed that a simple geometric-driven, empirical model does not seem to be where the project should stop, asking instead whether there might be more to it, Including, possibly why does higher temperature give a better joint; and what the underlying mechanism is. The reviewer posits that if answers to these questions were incorporated into the model it could be more easily generalized to new systems.

On Slide 13, the model is applied to new material pairs Mg-Al and Al-steel. The reviewer stated that he was not clear how the data presented was related to the model. The graphs on the right appear to be experimental results only. The reviewer asks if Slide 15 trying to convey that the model is making predictions of the weld energy needed for new material pairs or whether not this work had been validated or not.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer says that each of the national labs involved has clearly-enumerated responsibilities. Perhaps further input from industry would maximize the project’s impact.

Reviewer 2

This reviewer believed that the labs are using their strengths and coordinating well. The project might benefit from some industrial involvement.

Reviewer 3

This reviewer stated that the effort appears to be mostly an ORNL experimental effort with an empirical model to predict thermal response of the process, validated by thermal imaging. This work is directed at generating consistent mechanical response in lap shear testing. There were a few slides on characterization efforts but I am not sure how the characterization work was integrated into the other efforts. This may be simply a result of the limited presentation time available at the AMR. I look forward to seeing more detail in the Annual Report or in publications.

Reviewer 4

This reviewer said that the team is comprised of ORNL as a lead focusing on joining process, evaluation and characterization as well as modeling. ANL is investigating joint tomography and chemical composition while PNNL is using advanced electron microscopes to evaluate microstructures of the joint interface (both significantly smaller tasks than ORNL's work). Collaboration seems to be an appropriate leveraging each of the laboratories' core competencies in relation to this project.

Reviewer 5

This reviewer stated that, while this is a team of multiple national labs, the roles of the participants other than ORNL was not clearly laid out in the presentation.

Reviewer 6

This reviewer noted really good collaboration between national labs on this program but that it could use SME in welding such as TWI, etc.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the proposed future research is exactly on-par with the overall goals of the project. It seems likely that the team will make good progress towards these goals. However, it should be mindful of "failing fast" when it comes to exploring other non-USW material pairs that are relevant to automotive applications, as new and significant challenges may arise, especially when it comes to lap shear performance of the pairs. The team will need to identify the related challenges as quickly as possible.

Reviewer 2

This reviewer noted that there had not been a lot of time for questions and it was unclear whether the substrate surfaces were cleaned before being joined. This reviewer suggested that future work continue with the Thrust 4 modeling effort and make the ultrasonic rivet joining or ultrasonically assisted self-piercing riveting another subprogram.

Reviewer 3

This reviewer opined that there is a lot of work left to do to extend the project to a USW joint involving a mechanical fastener. The concept is good but it will be tight to finish in the allotted time.

Reviewer 4

This reviewer believed that future work seems appropriate to address the project goals. Fiscal year 2022 work will extend USW to join Mg-Al and Al-steel pairs based on findings from numerical models. Fiscal year 2023 will select one variant of the ultrasonic based joining technique to join other materials pairs that are not feasible with USW.

Reviewer 5

This reviewer said that future work needed clarification but the speaker had used up most of the time in the presentation leaving no time for reviewers' questions.

Reviewer 6

This reviewer thought that the thermal model validation, using different material pairs, will be an important proof point for the effort, although this type of model will always struggle with the geometric variability of each part/joint modeled. Future work should be directed at making the model versatile enough to be useful across all systems and geometries. To do that it might have to incorporate more of the fundamental mechanisms that make an ultrasonic joint strong.

The reviewer believed that the second bullet on the proposed future work slide on exploring new joining techniques feels somewhat out of scope. If the project is developing better and better conventional ultrasonic welds in dissimilar materials, that suggests continuing this work. There is a well know problem with spacing of ultrasonic welds and joint reliability. Solving that problem before moving to a new technique (ultrasonic riveting or ultrasonic self-piercing rivet [SPR] might be more valuable.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer stated that advanced joining will enable increased use of lightweight materials.

Reviewer 2

This reviewer said that the Al to galvanized DP590 steel joint is very relevant today, as this multi-material stack up is the most cost-effective way to lightweight vehicles. However, the Mg market price is so high today that it has driven applications to only high-performance niche vehicles.

Reviewer 3

This reviewer said that multi-material joining is an important and highly relevant topic and this project addresses some potentially useful solutions

Reviewer 4

This reviewer found that the work is relevant. Methodologies to join dissimilar materials are critical to enabling lightweight strategies across the VTO Materials mission space. Dissimilar joining strategies also have application in powertrain, electric drive systems and in an electrified infrastructure. Efforts here will have broad impact in multiple VTO subprograms.

Reviewer 5

This reviewer believed that the objective of this project is relevant to VTO materials subprogram as it aims to develop new solutions to multi-material joining to enable lightweighting. Ultrasonic spot welding is being investigated due to its fast welding cycle, low clamping force, and parts can easily be recycled due to no third material.

Reviewer 6

This reviewer believed that the project is relevant for developing multi-material joining that can be a key enabler for lightweighting.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer commented that the team appears to have the necessary technical background and experience to complete the work.

Reviewer 2

This reviewer said that program resources are being used sufficient.

Reviewer 3

This reviewer said that the resources should be sufficient to complete the project provided that the collaborators down-select quickly on the final tasks.

Reviewer 4

This reviewer expressed a little initial confusion about the project budget. The reviewer believed that the $983,000 was for the full 3 years, not just for fiscal year 22 as stated in the slides. The reviewer believes that this $328,000 per year seems adequate.

Reviewer 5

This reviewer noted that this is a three year lab annual operating plan funded project with a total fiscal year 2022 budget of $1 million, which seems appropriate for the outlined scope, the challenge it is addressing, and the opportunity ultrasonic spot welding presents for multi-material joining.

Reviewer 6

This reviewer said that the resources are sufficient.

Presentation Number: mat223
Presentation Title: Extending High Rate Riveting to New Material Pairs
Principal Investigator: Kevin Simmons, Pacific Northwest National Laboratory

Presenter

Kevin Simmons, PNNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

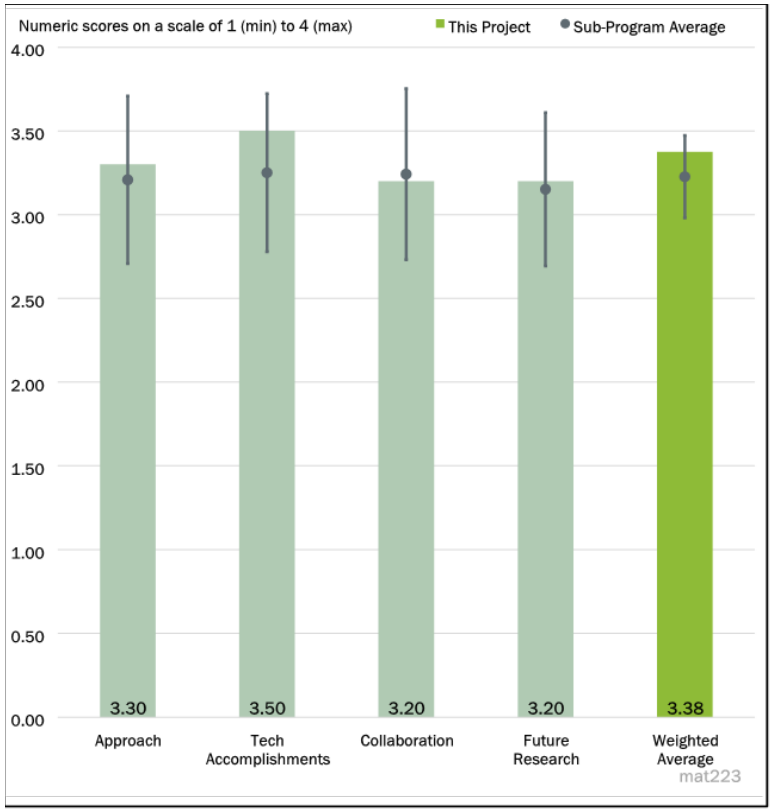

Figure 5-32 - Presentation Number: mat223 Presentation Title: Extending High Rate Riveting to New Material Pairs Principal Investigator: Kevin Simmons, Pacific Northwest National Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

This reviewer found the approach to be sound and comprehensive. Several technical barriers were clearly identified relating to joint quality and corrosion, but it appears that further investigation into corrosion will be part of future work. The team showed good use of the virtual environment to guide its work, and the suite of shear strength testing was well-designed to address technical barriers. However, the reviewer noted that peel testing does not appear to have been pursued at all.

The reviewer stated that the use of vacuum sealing to slow the degradation of plasma treatment was well-presented. However, the reviewer found the slides to be unclear as to whether this mitigation strategy can last for the lifetime of the part. It would also be interesting to know if this can be predicted through modeling.

Reviewer 2

This reviewer found that the tasks designed are adequate to address the barrier of the project. The efforts among modeling/mechanical test/characterization/process are well balanced.

Reviewer 3

This reviewer characterized the project as a comprehensive approach to correlate the effect of process joining on joint microstructure and bond strength for high-velocity rivet (HVR) and high-rate friction rivet (HFR).

Characterization, mechanical fastening, hybrid joining, modeling, and mechanical testing are integrated in the approach to develop new and novel high-speed joining techniques with multi-material systems.

Reviewer 4

This reviewer said that the technical barriers are well addressed. The project is well designed for achieving the milestones. Experiment and modeling are combined for investigating the processes. The connection with and role of industry are less clear.

Reviewer 5

This reviewer believes that the team is doing a good job. Program and testing of joints are proceeding. The project is well planned and the timeline is reasonable. The reviewer noted that reverse engineering to create the model for the cohesive properties of the bond that better recreate the experimental behavior will be determined using an FE model (riveting + lap shear).

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

This reviewer felt that the team did well addressing their first two milestones, and based on the progress presented, the team appears to be on track for milestone 3- milestone 5. The improvement in lap shear performance using plasma treatment is very clear in the team's experimental results, and the model correlation looks strong so far. It is impressive and impactful that the team developed a new method to enable calculation of fracture energy of dissimilar material joints, but further discussion of the mechanism behind the size-effect method would have been helpful.

Reviewer 2

This reviewer found the structure/interface characterization and performance evaluation of HVR/HFR of dissimilar material to be of high quality. The use of advanced characterization tools at national laboratories improves mechanistic understanding of the joining process.

Reviewer 3

This reviewer found accomplishments, including development of nitrile rubber (NBR) adhesives and surface modification and use of plasma treatment to increase joint strength to be significant and noted that the milestone for surface modified Al optimized for lap shear adhesion with HVR had been met.

Reviewer 4

This reviewer noted that the Technical Milestones 1 and 2 have been achieved within the planned timeline and found he progress to be on track.

Reviewer 5

This reviewer was unclear about the total number of tests completed asking if it is approximately 150+ including replicates at different geometries.

The reviewer found it interesting that finding that the conventional ASTM method of modified beam theory did not yield good results due to scatter while the size-effect method (G_{IC}) had good results.

Regarding the rivet break off, the reviewer noted that it was flush with the material while sometimes it would be desirable to have mechanical lock on top surface. The reviewer liked the X-ray component testing scan results.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer fount that the responsibilities for collaboration/contribution have been clearly enumerated for PNNL, ORNL, and ANL. The team included several commercial materials in their research, in collaboration with industry stakeholders.

Reviewer 2

This reviewer stated that the collaboration is strong within the project team.

Reviewer 3

This reviewer said there was good collaboration between national labs and industry but that it would possibly be desirable to get fastener SME involved (Stanley, Henrob, etc.).

Reviewer 4

This reviewer said that several collaborations were noted, including with ANL on joint characterization, with ORNL on NBR adhesive and plasma treatments, with corrosion team to investigate corrosion inhibition, and with HVR and HFR teams at PNNL to develop hybrid joining methods.

Reviewer 5

This reviewer said that Argonne doing some characterization was mentioned, but exactly what was the significance of Argonne National Laboratory contributions was not explained. The future plan does not call out what the different labs are doing. The industry contributions as advisors are unclear.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the proposed future work addresses several different aspects of the project and will require very carefully managed collaboration.

Reviewer 2

This reviewer suggested that the fading of plasma treatment is worth looking into as it has a strong impact on the actual use of the NBR adhesive.

Reviewer 3

The reviewer said Al substrate sometimes uses a conversion coating (zirconium, etc.) to help with adhesive bonding strength instead of tape maybe look to overcome paste adhesive with/without glass bead that did not improve the performance of HFR joints and/or laser treatment methods for surface modifications.

Reviewer 4

This reviewer found that the proposed future work seems appropriate to address the outstanding barriers and meet the objectives of this project. Demonstrating joining on the component level and industrial engagement are important.

Reviewer 5

This reviewer pointed out that the future work was rushed during the presentation, but the plan forward is clear. The connection with industry needs to be clarified.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer believed that the project may enable further use of lightweight materials by enabling joining of dissimilar materials that are presently difficult to join.

Reviewer 2

This reviewer was not sure how relevant substrate to same substrate joining is compared to dissimilar materials joining. In addition, HFR process development for new material combinations with different surface modifications is a good idea but I am not certain how relevant.

CFRP-AA5052 or AA5052-DP590 would be / what is the application?

Reviewer 3

This reviewer says that the project clearly supports the objective of "Materials" subprogram in VTO.

Reviewer 4

This reviewer found that the project is relevant to the lightweighting materials subprogram objectives as joining multiple dissimilar materials of Al, steel, and composites is complex. Successful demonstration of high-rate riveting will increase process efficiency, enable innovation and sustainable manufacturing process and joining of dissimilar materials to enable creation of high-performance lightweight structures.

Reviewer 5

This reviewer answered that the project supports the program objectives. The work of this project supports the lightweight materials objective and supports development of sustainable manufacturing methods.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the resources available across the three national labs should be sufficient, given the collective equipment and expertise available.

Reviewer 2

This reviewer said that the program resources being used are sufficient.

Reviewer 3

This reviewer said that the resources are sufficient to address the goal of the project.

Reviewer 4

This reviewer said that the project funding seems appropriate ($2 million over 3 years) given the scope and collaborations among partners.

Reviewer 5

This reviewer said that the resources for accomplishing the milestones of the project seem adequate.

Presentation Number: mat224
Presentation Title: Solid State Joining of Multi-Material Autobody Parts Toward Industry Readiness
Principal Investigator: Yong Chase Lim & Piyush Upadhyay, Oak Ridge National Laboratory/Pacific Northwest National Laboratory

Presenter

Yong Chase Lim & Piyush Upadhyay, ORNL/PNNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

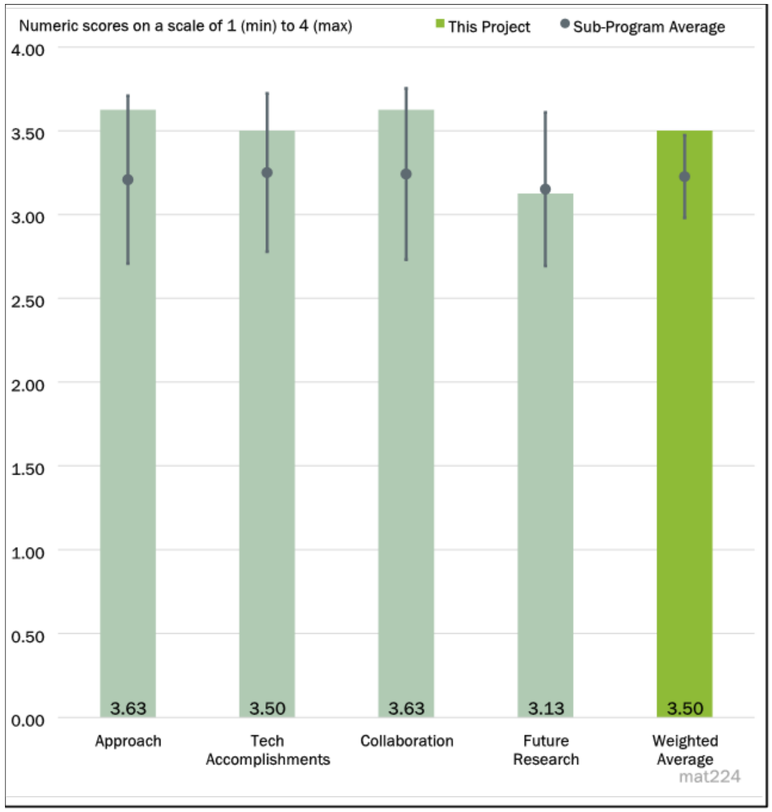

Figure 5-33 - Presentation Number: mat224 Presentation Title: Solid State Joining of Multi-Material Autobody Parts Toward Industry Readiness Principal Investigator: Yong Chase Lim & Piyush Upadhyay, Oak Ridge National Laboratory/Pacific Northwest National Laboratory

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that the project is well designed to overcome the barriers. The goals and milestones are very clear, and they seem to be on track.

Reviewer 2

This reviewer felt that the team is doing a great job. The program is well defined with real life applications, noting that it is not easy to take samples from the lab and scale up to production rate robotic platform (1 m/min).

Reviewer 3

This reviewer suggested that to enable scaling up production, perhaps the project can also provide recommendations/guidance on the QC methods that the production line can adapt for efficient examination of the joint, based on the likely failure mode found in the study. The process window should be accessed as well.

Reviewer 4

This reviewer said that the approach consists of maturing two national lab-developed solid state joining processes towards industrial readiness.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer found that the first two milestones have been achieved. The progress was very well demonstrated. Repeatability of welding process is demonstrated and connection with industry transfer was made. Progress on both friction stir linear welding (FSLW) and friction self-piercing rivet (F-SPR) processes was well presented.

Reviewer 2

This reviewer said that the team had developed a good technical process.

Reviewer 3

This reviewer said that the project team successfully demonstrated two joining process using a robot.

Reviewer 4

This reviewer noted that the team of multiple national labs has made good progress towards implementing FSLW and F-SPR towards higher volume production.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer said that there is really excellent collaboration on this program but suggested that involving Hitachi for FSW high volume production scale up lessons learned would be desirable.

Reviewer 2

This reviewer noted that the contributions of the two labs and of the industry partners are very clear. The synergy for the project needs is great.

Reviewer 3

This reviewer noted that this a large team with multiple key players to make this project successful.

Reviewer 4

This reviewer noted that the goal is to implement stir based joining methods in a production environment, but the involvement of industry seems to be minimal and questioned what the major barriers are for industry to adapt the developed technique.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer found that the proposed work is very clearly defined and connected to barriers and to the goal for high volume production.

Reviewer 2

This reviewer found a need to model more of how to deal with thermal effects on table and secure x, y, z forces at higher welding speed/temperature. The reviewer urged that the difficulty of achieving the 6022 outer class A surface finish not be underestimated and suggested looking at beryllium (or other lightweight, stiff materials) fixtures to address robotic arm stiffness issue.

Reviewer 3

This reviewer said that the process window of the technique should be evaluated, specifically that the recommendation of a quality control tool will be valuable for the industry. Evaluation of corrosion performance is included in the future work. The fatigue performance of the joint is also important.

Reviewer 4

This reviewer said that the proposed research is satisfactory but still focused on lab scape coupon evaluation.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the project is very relevant today, as multi-material is the most cost-effective way to lightweight vehicles.

Reviewer 2

This reviewer said that the project objective is in-line with VTO's goal.

Reviewer 3

This reviewer said that the project supports the light-weighting mission through joining technology development.

Reviewer 4

This reviewer said that the work supports the program's objectives for lightweight materials and potential for commercialization.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer found that the funding is sufficient for the proposed work.

Reviewer 2

This reviewer found that the resources are sufficient for project execution.

Reviewer 3

This reviewer found that the resources seem to be adequate for the proposed work.

Reviewer 4

This reviewer believed that the program clearly needed more resources but that the program is on target because industrial partner(s) increased resources to meet those needed to be successful.

Presentation Number: mat225
Presentation Title: Surface Modifications for Improved Joining and Corrosion Resistance
Principal Investigator: Yong Chae Lim & Vineet Joshi, Oak Ridge National Laboratory/Pacific Northwest National Laboratory

Presenter

Yong Chae Lim & Vineet Joshi, ORNL/PNNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 25% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 50% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

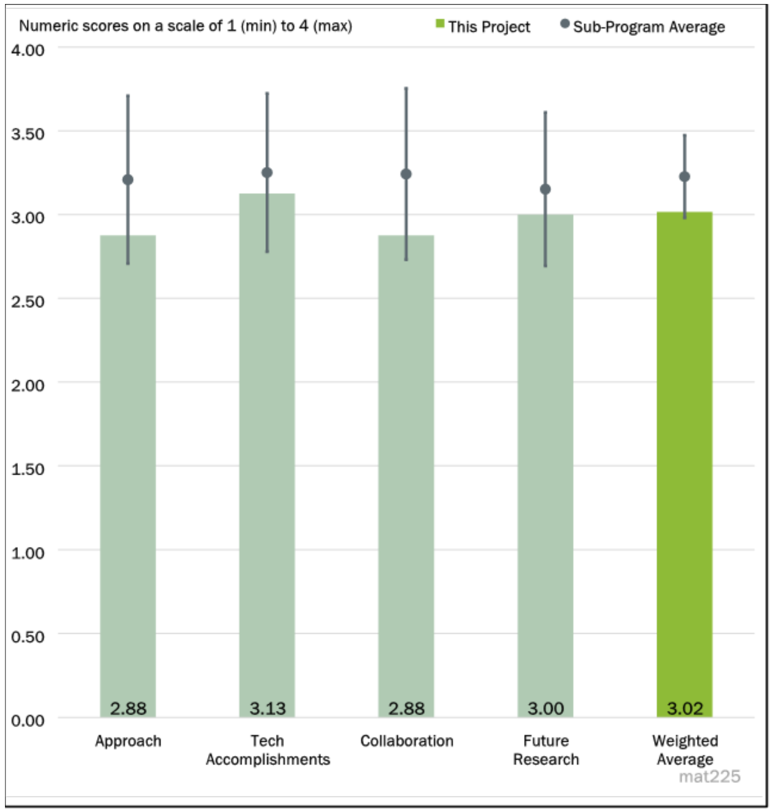

Figure 5-34 - Presentation Number: mat225 Presentation Title: Surface Modifications for Improved Joining and Corrosion Resistance Principal Investigator: Yong Chae Lim & Vineet Joshi, Oak Ridge National Laboratory/Pacific Northwest National Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

This reviewer found the approach to be all very good but that more ties with contemporary research would be welcome, as would motivation for exact methods used in experiments and modeling. Investigation of crevices under rivets also seems to be appropriate, in-scope, and not explored yet.

Reviewer 2

This reviewer said that the proposed approach is comprehensive, including process, characterization and numerical modeling. A model validation could be included.

Reviewer 3

This reviewer said that the approach is a shotgun approach to the topic and is too broad in the reviewer’s opinion to address some of the fundamental questions. This project attempts to do too much with too little. The team uses Comsol to provide a direction in respect to corrosion. However, there are two other projects focused on corrosion modeling which the reviewer believes should be investigated for potential leverage opportunities (an ongoing project with WPI, and one already completed led by UofM).

Reviewer 4

This reviewer said that the reliance on corrosion simulation and electrochemical impedance spectroscopy (EIS) measurements (which have not always shown good correlation to real world field corrosion experience or to automotive industry standard accelerated corrosion aging evaluation procedures) would be better if some automotive industry accelerated aging (corrosion) tests were used for validation. The reviewer believed that use of vacuum sealing (as shown on one of the backup slides) to prevent (or at least slow) surface energy deactivation is not a feasible production solution to the rapid degradation in surface energy. Even with vacuum sealing, the drop-off of surface energy on AA6061 was substantial and may completely negate the value of the process for this material for real world production use. This drop-off should have been discussed in the main body of the report (at the very least included on the "Remaining Challenges and Barriers" slide) and not hidden away in the backup slides.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer found that good progress had been made in all regards.

Reviewer 2

This reviewer noted that on the slide of "milestones" only checks are marked on the status. It is unclear this refers to a 100% completion or that work is proceeding on it.

Reviewer 3

This reviewer found that the project team has made good progress in scientifically evaluating and characterizing plasma treatments on Al, steel, and CFRP. However, the report does not include any lap shear test results even though they were supposed to have been completed as part of the go/no-go decision from 9/30/21, or results from the quarter 6 dissimilar material joining feasibility task, even though that work should have been completed in time for inclusion in this report.

Reviewer 4

This reviewer noted that the project has continued work despite COVID and in that context, appropriate progress has been made. A continuous laser was employed because of technical failures. However, the industry standard is a pulsed laser. This should be considered in planning for future work.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer said that the project team has made connections across labs and across topics. However, the reviewer believed that these connections, only scratched the surface at the cost of depth—exploring some of the fundamental issues facing industry in this area.

Reviewer 2

This reviewer felt that deeper collaboration with industry, beyond periodic conversations, would better assure use of these results in commercial applications.

Reviewer 3

This reviewer noted that the project is now in its second year, suggesting that the team should possibly speed up finding/reaching the industrial partner.

Reviewer 4

This reviewer said that the project indicates good collaboration within the project team of laboratory partners. However, while "periodic interactions with other thrusts within JCP with close coordination/ties to automotive industries" are mentioned on the "Collaboration and Coordination" slide, there is no mention anywhere in the report of how that information is being shared or used in the project.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer stated that the proposed future work meets the research goal and addresses the research challenges.

Reviewer 2

This reviewer found the approach to be steadfast and quite good but subject to the reviewer's comments above.

Reviewer 3

This reviewer said that the project needs to include some automotive industry standard accelerated corrosion evaluation and mechanical testing to validate the modeling and EIS evaluations.

Reviewer 4

This reviewer noted that the proposed future work touches on interesting topics but did not see a well thought out, integrated approach. For example, control of oxidation is noted under atmospheric plasma but laser ablation also creates a new oxide layer. The reviewer asked why not include that process or even alodine coated surfaces as the baseline oxide in an investigation of what oxide surface is best and why. Also, the project did not use a pulsed laser for their ablation work (which is the norm for industry) which may limit the applicability of their learnings.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer pointed out that the DOE is interested in greenhouse gas emission reductions. Application of lightweight materials supports this goal. In order to actualize application of the right material in the right form in the right application, it is imperative to achieve dissimilar material joints. The current strategy for such joints are hybrid joining solutions involving adhesive bonding. According to the reviewer, the understanding of the adhesive/substrate interface under environmental exposure is imperative to dissimilar material joints.

Reviewer 2

This reviewer said that corrosion is essential to future vehicles, making this an important topic area.

Reviewer 3

This reviewer said that joining of dissimilar materials is an important area in advanced manufacturing for DOE to reduce the structural weight and improve component performance and energy efficiency. Corrosion is a critical barrier in broadening the application of dissimilar materials joints. This research aims to address this issue by modifying the bonding surfaces to improve the galvanic corrosion resistance.

Reviewer 4

This reviewer said that the project supports VTO objectives by investigating methods to reduce galvanic corrosion and improve adhesive bonding for multi-material joining.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer believed that the funding seems to be aligned with work being performed.

Reviewer 2

This reviewer believed that the amount of resources is too little to address the scope of fundamental questions in the space the project explores. The reviewer suggested that the project team should define the starting and ending Technology Readiness Level, which would help to define the resources needed.

Reviewer 3

This reviewer believed that the national laboratories have enough resources to fulfill the research goals on time.

Reviewer 4

This reviewer found that the project budget ($3.225 million) seems excessive for the relatively narrow scope of the project and the almost complete reliance on modeling and small scale laboratory tests with very little in the way of actual dissimilar joint mechanical testing and automotive industry standard corrosion evaluation, and, importantly, mechanical testing after exposure to automotive industry accelerated corrosion exposure.

Presentation Number: mat226
Presentation Title: Machine Learning for Joint Quality and Control
Principal Investigator: Zhili Feng and Keerti Kappagantula, Oak Ridge National Laboratory/Pacific Northwest National Laboratory

Presenter

Zhili Feng and Keerti Kappagantula, ORNL/PNNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

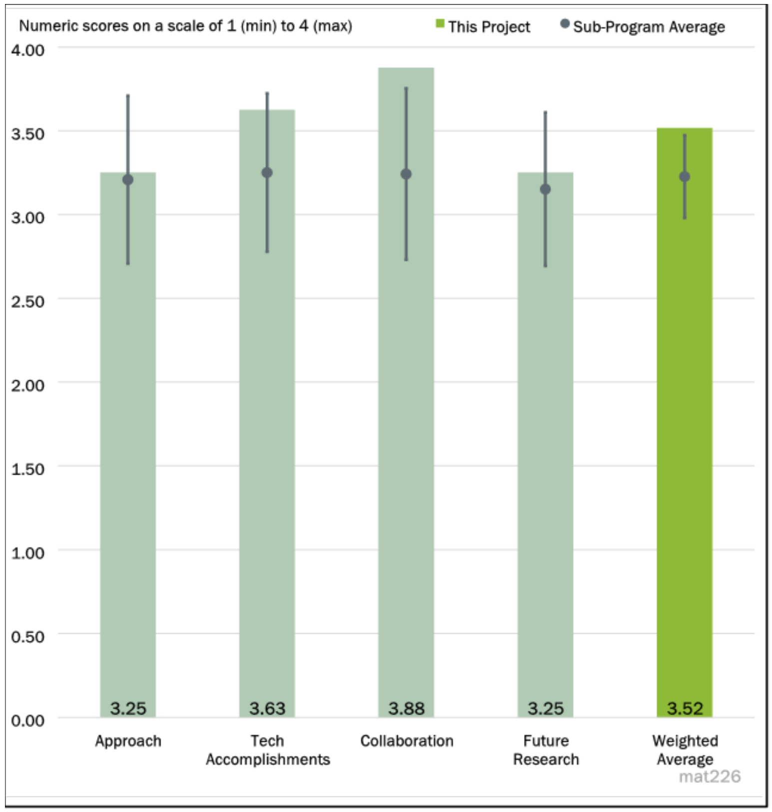

Figure 5-35 - Presentation Number: mat226 Presentation Title: Machine Learning for Joint Quality and Control Principal Investigator: Zhili Feng and Keerti Kappagantula, Oak Ridge National Laboratory/Pacific Northwest National Laboratory

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer believed that the project represents very modern, innovative and industry supported work. Great to have such a large a data set with machine learning.

Reviewer 2

This reviewer believed that this is an excellent project and the large dataset from General Motors (GM) is a major asset for the work. The reviewer was curious about the scale of the joint specimens included in the dataset (whether they were samples or full-scale specimens) as this relates to the CTE mismatch and “unexpected” thickness-dependent baking effects. Length scale (not just of the joint but also the interfacing components) will be important to validate accuracy and extensibility of the thermal stress models being developed in the mechanistic portion of the work—particularly considering that the plate thicknesses were found to be some of the most important predictors of weld performance.

Reviewer 3

This reviewer pointed out that machine learning is an effective approach to link the materials/process conditions, microstructure, and joint properties. PNNL tested random forest model to link materials/process conditions and joint properties. ORNL applied a deep neural network to identify the important features and revealed unexpected thickness-baking effects. How to link the process to microstructure is unclear.

Reviewer 4

This reviewer said that the project is well designed and the timeline is reasonably planned to accomplish the stated goals. But, it is not obvious that this project will help to significantly reduce process delays for developing and optimizing new joining process/substrate combinations beyond those being evaluated as part of the project because the methods used in this project presuppose a large existing database (GM provides over 30 GB of resistance spot welding data) that is then used to train the ML for providing predictive capabilities for very minor variations (for example, replacing 1.2 mm thick Al with 1.1 mm thick Al) to the original test.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer found the project to be a very impressive use of new technology (neural network [NN]) to address an old problem (RSW).

Reviewer 2

This reviewer believed that the technical accomplishments (substantial predictive validations with over 80% accuracy) are impressive and seem to support the project approach very well.

Reviewer 3

This reviewer believed that excellent progress is being made in this project, especially relative to project size.

Reviewer 4

This reviewer noted that PNNL has accomplished one milestone and has four left; and ORNL finished two milestones and has two milestones left. The process is on the right track.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer found that there appears to be excellent collaboration with GM. It would be great if students could be involved to improve technology transfer.

Reviewer 2

This reviewer said that the collaborators appear to be very well coordinated in this project.

Reviewer 3

This reviewer said that , the partners/collaborators seem to be working well together in a complementary fashion, and did not identify any potential improvements in this area.

Reviewer 4

This reviewer said that the team consists of two national laboratories and one industrial partner. PNNL and ORNL will work with the weld data provided by GM with different machine learning methods.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer believed that there was not too much real detail given but the project seems on a very good track.

Reviewer 2

This reviewer said that the proposed future work meets the research goal very well.

Reviewer 3

This reviewer said that the proposed future work is well suited to overcoming remaining barriers to achieving the project goals.

Reviewer 4

This reviewer said that the future work plan specifies identical future work for both laboratories and believed that this will need to be well coordinated.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer noted that RSW remains the dominant mode for metal joining. Extensive study of this area is very appropriate.

Reviewer 2

This reviewer believed that joining of dissimilar materials is a critical area in advanced manufacturing for DOE to reduce the structural weight and improve component performance and energy efficiency. Machine learning will accelerate the understanding of process-structure-performance relationships and the development of dissimilar material welding processes. Machine learning will also help identify unexpected important parameters, as the results presented by ORNL.

Reviewer 3

This reviewer said that the project is well aligned with DOE objectives in multimaterial joining.

Reviewer 4

This reviewer said that the project is relevant in that it is aimed toward helping to reduce process development delays for joining lightweight dissimilar materials. However, concerns about the ability to successfully adapt this work to other joining methods may reduce the relevance somewhat.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer found that the budget seems to be appropriate.

Reviewer 2

This reviewer said that the national laboratories and industrial partner have enough resources to fulfill the research goals on time.

Reviewer 3

This reviewer found the resources to be sufficient.

Reviewer 4

This reviewer said that, given the scope of the project, the budget and timing seem to be about right. The reviewer would expect this project to be completed successfully and on time.

Presentation Number: mat229
Presentation Title: Development of a Novel Magnesium Alloy for Thixomolding of Automotive Components
Principal Investigator: Govindarajan Muralidharan and Bryan Macek, ORNL/FCA LLC

Presenter

Govindarajan Muralidharan and Bryan Macek, ORNL/FCA LLC

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

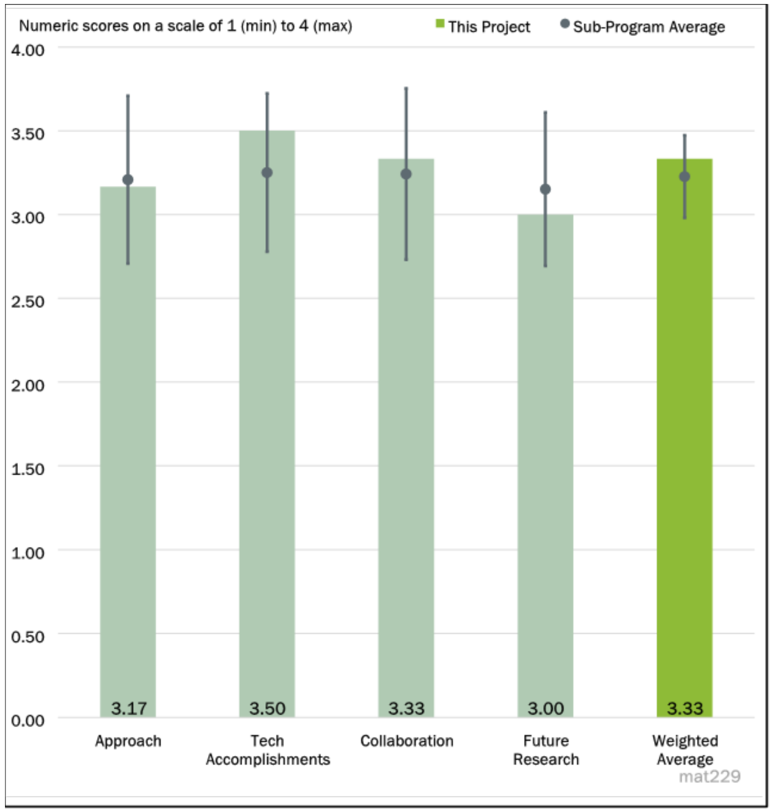

Figure 5-36 - Presentation Number: mat229 Presentation Title: Development of a Novel Magnesium Alloy for Thixomolding of Automotive Components Principal Investigator: Govindarajan Muralidharan and Bryan Macek, ORNL/FCA LLC

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that the approach taken to execute the work is good. The technical barriers seem to be addressed in a way that would result in meeting the stated goals of the project.

Reviewer 2

This reviewer said that the project is set up well, targeting an alloy, with clear metrics and an industrial application. This is a good blend of research and engineering. The reviewer thought that it would be useful to have one or more component level tests as part of the test plan, perhaps a structural test if the application has one. Also useful would be to have a list of metrics for the performance of the thixomolding process itself. The parts will go to Stellantis for analysis but the reviewer found it not clear what that analysis entails (surface quality, absence of cracking, wall thickness consistency, etc.). Those metrics should be applied to determine the efficacy of the alloy development method and confirm the hypothesis that something that blends the best properties of AM60 and AZ91 is really the best alloy for thixomolding.

Reviewer 3

According to this reviewer, while the approach to designing the new alloys seems to be clear, the project leaders reasons for choosing extrusion over thixomoulding to confirm the benefits of the new alloy compositions are not. It is clear that extrusion will yield different results to thixomoulding. Thixomoulding trials appear to be part of the project plan.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer noted that the alloys have been downselected and the project is proceeding to produce the chips and fabricate the part. The delay due to COVIDCOVID protocols is recognized and the no-cost extension is already in place so it appears the project is still on track.

Reviewer 2

This reviewer stated that the PIs have developed the compositions of Mg alloys that look very promising. Tests carried out to date validate the initial optimism surrounding these alloys. The accomplishments and progress of the work are good.

Reviewer 3

This reviewer said that the benefits of the new alloy systems at lab scale seem to be clear.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer believed that the project team appears to be taking guidance and working well with the industrial partners. Modeling analysis has provided many candidate alloys for down-selection and seems to be a good example of the use of ICME for alloy development. It will be interesting to see how well these downselect parameters are good a predicting thixomolding performance.

Reviewer 2

This reviewer said that the collaboration seems to be good.

Reviewer 3

This reviewer said that the collaboration between ORNL and FCA (corrosion testing) was evident. Less evident are the synergies with Magnesium USA and Leggera. The reviewer is not saying that it does not exist, just that it was not highlighted beyond mentioning them on Slide 20. However, the synergies that are shown appear to work well.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer found the plan to look good overall. However, in addition to the three proposed items, a quantitative analysis of the thixomolding process parameters impact on part properties such as surface quality, defects, filling, etc. would be an important output as well.

Reviewer 2

This reviewer thought that corrosion testing on prototypical specimens, as opposed to just coupons, will be prudent. Corrosion that is more severe or more localized sometimes shows up on prototypical specimens (that does not show up on coupons) due to the processing and prior strain history of the fabricated part.

Reviewer 3

This reviewer stated that, while the project end appears near, it is important to include the right process as planned.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer opined that thixomolding is a good candidate for the production of Mg alloy parts that can overcome a lot of the challenges of die casting and other processes to produce components in this alloy.

Reviewer 2

This reviewer believed that the work touches on Materials and Efficient Mobility Systems because the lightweight alloy formulations will contribute to weight reduction and better fuel efficiency in vehicles.

Reviewer 3

This reviewer pointed out that the ductility level achieved shows great promise to expand the field of application of Mg in vehicles.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer noted that the project was delayed but the participants have taken this into account and the project is well scoped to complete in the remaining time needed.

Reviewer 2

This reviewer said that, by the PI's own admission, the resources are adequate. This reviewer sees no reason from the work presented to dispute this claim. More time will be needed to complete the work as evidenced by the no cost extension applied for by the PIs (and granted by VTO).

Reviewer 3

This reviewer found that there seem to be sufficient resources.

Presentation Number: mat235
Presentation Title: Light Metals Core Program - Thrust 4 - Residual Stress Effects
Principal Investigator: Ayoub Soulami, Pacific Northwest National Laboratory

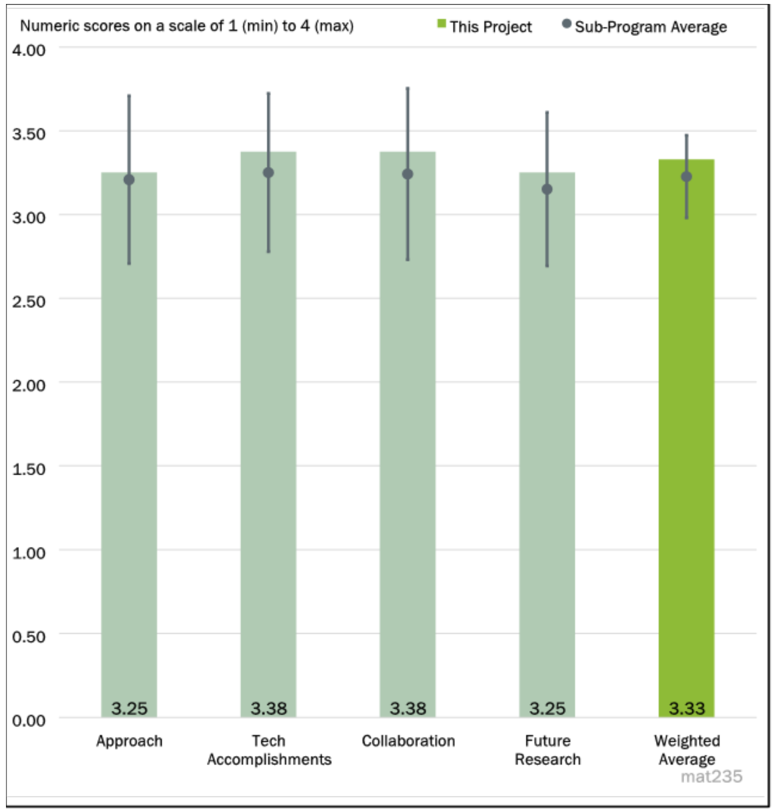

Figure 5-37 - Presentation Number: mat235 Presentation Title: Light Metals Core Program - Thrust 4 - Residual Stress Effects Principal Investigator: Ayoub Soulami, Pacific Northwest National Laboratory

Presenter

Ayoub Soulami, PNNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

This reviewer said that the goals and objectives are clear. The plans for modeling and experimentation to understand and characterize residual stresses are very well-developed. The one remaining milestone (M2.0) appears to have been allotted sufficient effort, particularly because many of the learnings from M1.0 can be applied.

Reviewer 2

This reviewer described the project as a cross-cutting ICME effort, supporting several different projects within the Light Metals Core Program (LMCP). It is developing computational modeling approaches to predict residual stresses resulting from friction-stir processing, ShAPE tube extrusion, and bending-unbending processing, with an ultimate goal of guiding design of processing methods to reduce residual stresses and ensure dimensional stability. It has pursued a mix of Thermo-Pseudo Mechanical (TPM), Smoothed Particle Hydrodynamics (SPH), and FEA methods and imports constitutive models as needed. It would be helpful in future reviews to define the technical barriers associated with the development of these ICME methods with the level of accuracy required to meet the goals in the different programs it is supporting.

The reviewer asked how good is good enough in the computational predictions; are the constitutive models sufficiently well developed or do they need to be further improved; and what the tradeoff is between accuracy and computational speed required. Although the progress demonstrated was impressive, it is not clear to the reviewer what technical barriers had to be overcome and will need to be overcome in the development of the ICME models.

Reviewer 3

This reviewer believed that the work needs to start with some baseline manufacturing processes where the residual stress effects are more experimentally measured and understood. It is important to validate the computational models in the baseline processes before tackling the residual stress prediction in the new processes with local enhancement.

Reviewer 4

This reviewer observed that the project is an effort within LMCP and focuses on residual stress measurements and modeling although the focus so far has been on the modeling within the project.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer found impressive progress to have been demonstrated in the prediction of residual stresses and on the use of the models to test how they could be reduced in friction-stir processing (FSP) through design of processing parameters and clamping conditions. In the validation tests, some notable discrepancies with experimental measurements (e.g., in Slides 10 and 11) were noted and it was not clear whether these are significant for the intended use of the models in the relevant projects, and, if so, what would be the plan to improve the model accuracy.

Reviewer 2

This reviewer noted that the team has made great progress and appears to be on track. M1 is complete, and there are no major “red flags” that would prevent progression from M1 to M2. The model appears to work fairly well as-is, but will likely need further iteration and improvement to accommodate a broader range of component sizes and geometries. Iterative correlation using both the virtual and experimental environments should be a major priority moving into M2.

Reviewer 3

This reviewer found the results to be impressive despite being on small and simple samples.

Reviewer 4

This reviewer said that several good examples were provided where successful residual stress models were developed (e.g., ShAPE tube extrusion).

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer pointed out that, since this is a cross-cutting project, it involves collaboration with the other LMCP projects and such collaborations are essential to drive the model development and for the models to be used to advance the goals of the other LMCP projects. The examples presented suggest these collaborations are well coordinated.

Reviewer 2

This reviewer said that as a cross cutting project, the project is supporting several projects within the LMCP program. The reviewer suggested that the team could develop collaboration with universities to leverage more expertise in the area.

Reviewer 3

This reviewer noted that PNNL, ORNL, and ANL collaborated on this project. Further coordination with industry as tests are being developed would be beneficial in order to maximize the impact of the work.

Reviewer 4

This reviewer said that all examples were provided from one national lab's projects and the project will interface with another national lab in the future.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer found the proposed future work to be clear and reasonable, and that it addressed key technical barriers. The reviewer opined that improving predictive modeling and focusing on larger components will increase the reliability of the method and validate its usefulness to industry stakeholders.

Reviewer 2

This reviewer suggested planning to focus on more complex components.

Reviewer 3

This reviewer suggest that it would have been helpful to see more detail on Slide 19 about the future research plans and specific targets Including what specific model development efforts will be needed, what defines success, what are the anticipated challenges and risks to achieving the targets.

Reviewer 4

This reviewer said that the proposed plans are good.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that this cross-cutting project appears to be well integrated to support the goals of the LMCP program, through advancing ICME approaches that can guide the development of scalable, cost effective, processing methods to locally enhance the properties of Al and Mg to enable broader implementation of lightweight alloys.

Reviewer 2

This reviewer believes that helping designers predict and reduce residual stresses will enable further use of locally-enhanced lightweight materials in high-strength applications.

Reviewer 3

This reviewer said that the project is supporting many light-weighting projects.

Reviewer 4

This reviewer said that the project is relevant for the light-weighting mission as local property enhancement may lead to unforeseen residual stress effects.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer noted that, given the level of progress realized in the first year, the evidence is that the resources are sufficient. However, related to comments in response to Question 8, it is difficult to assess if the further resources might be necessary going forward in the absence of more detailed milestones.

Reviewer 2

This reviewer believes that it does not appear that further resources will be required.

Reviewer 3

This reviewer found the resources to be sufficient.

Presentation Number: mat236
Presentation Title: Advanced Characterization and Computational Methods
Principal Investigator: Thomas Watkins, Oak Ridge National Laboratory

Presenter

Thomas Watkins, ORNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

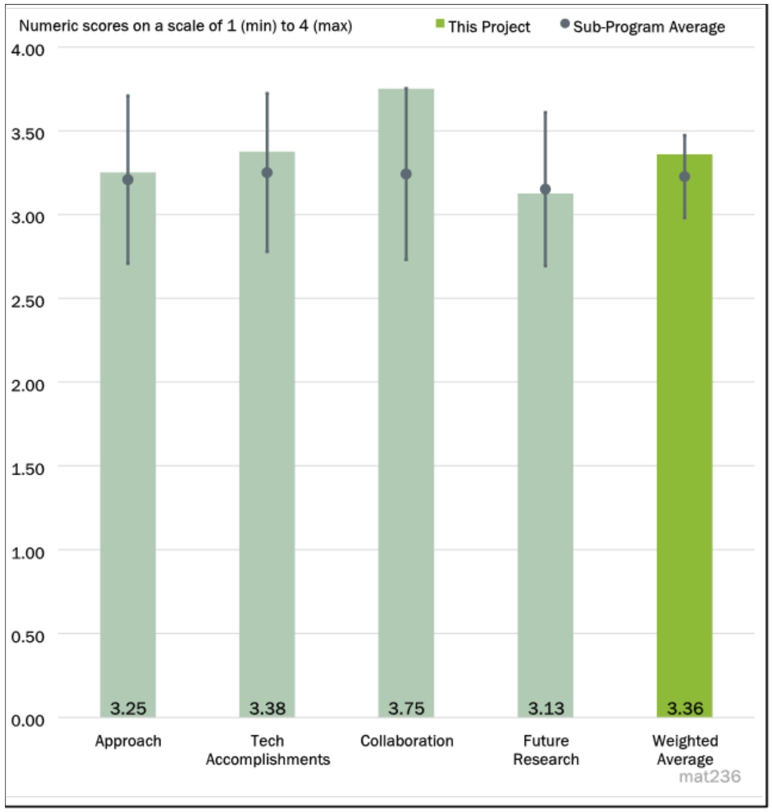

Figure 5-38 - Presentation Number: mat236 Presentation Title: Advanced Characterization and Computational Methods Principal Investigator: Thomas Watkins, Oak Ridge National Laboratory

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that the cross-cutting approach to Thrust 4 is a good example for other projects and that the team's integration throughout the program is impressive.

Reviewer 2

This reviewer believed that the team had developed a tremendously powerful model for how resources should be set aside for distinct characterization and computational support. The results across a number of programs is noteworthy.

Reviewer 3

This reviewer noted that resources from several labs are being applied. The tools for both the experimental observation of the molecular structure and the supporting computation demonstrate impressive capability.

Reviewer 4

This reviewer believed that, in many cases, the project lacks identification of key microstructural features to the properties they are controlling. In other cases, the reviewer thought that the work is relevant to internal combustion engines and not EVs. Regardless, before applying a particular characterization technique, the specific controlling microstructural feature(s) should be identified.

According to the reviewer, in Slide 3, the focus appears to be EVs, which do not see high temperatures and pressures. This is why getting heat into the passenger compartment is a problem and auxiliary heating is needed, unlike with internal combustion engines that provide all the heat needed for heating the passenger compartment in winter. EVs do not see 900°C so the need to study creep-resistant austenitic alloys is not clear.

The reviewer says that the team is going after lightweight, conductive, improved magnetic properties, and lubricants. The reviewer is not sure why lubricants are included.

The reviewer questions the purpose of developing coarsening-resistant additive manufactured Al-cooper (Cu)-Mn-zirconium (Zr) alloys. Specifically, which EV components need this property. Regarding Slide 16, the reviewer asked what is the ceramic material, how was it made, and what is the application. Regarding Slide 18, the reviewer finds that the purpose of carbon within ShAPE formed Al conductor is well described. However, the reviewer said that there is no mention of correlating the high resolution microstructure to properties. The reviewer asks how the electrical conductivity of these materials compares with the base materials.

Regarding Slide 25, the reviewer said that the slide talks of electrical properties but then goes into precipitates, which are generally not favorable for conductivity.

Regarding Slide 28, the reviewer asks why does the modeling mingle light duty engines with EVs.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

This reviewer pointed out that the support given to the extensive publications tally over the past few years certainly underscores the importance of the computational component to the VTO program efforts. The characterization component is equally critical, particularly from the standpoint of providing an avenue for singular capabilities that would otherwise be difficult to incorporate into shorter-duration programs.

Reviewer 2

This reviewer noted that Task 4B1-22 is making thermophysical data available for commercial software distribution. This facilitates dissemination of lab findings in a relevant and useful form for industry designers. That several publications have come out of this effort also demonstrates a focused effort to disseminate knowledge gained.

Reviewer 3

This reviewer found that all of the experimental examples are impressive and provide useful insights into the material behavior. Using scanning transmission electron microscopy (STEM) to improve the density functional theory (DFT) predictions is impressive. It is interesting that only STEM was able to identify the configuration of the lowest energy state for the interface.

Reviewer 4

This reviewer suggested that the microstructural work appears to be singular and no sample set with an experimental variable is included, which may show a property trend that can be related back to microstructure.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer believed that the presentation demonstrated how the computation team and experimental team in Task 1A1-21 are joining together to interpret and resolve molecular structure behavior questions around semi-coherent interfaces that could previously not be explained by modeling alone. This collaboration shows both effective utilization of the tools available and excellent cross collaboration between traditional workflow 'silos'. The tools for both the experimental observation of the molecular structure and the supporting computation appear to the reviewer to be well utilized in this collaborative environment.

Reviewer 2

This reviewer said that this is a well-structured team.

Reviewer 3

This reviewer said that the collaboration is impressive, since each project involves many different institutions.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer suggested that more details on proposed future work could be shared, noting that only 1out of 34 slides addresses future work, despite 15 months remaining in the timeline, and that a mapping of baseline characterization milestones for each task would be good to see.

Reviewer 2

This reviewer found the future plans to be clear and to make sense.

Reviewer 3

This reviewer requests that the team provide clear statements that mention studies which include the effect of chemistry or process on properties and which specific microstructural feature(s) will be studied for correlation.

Reviewer 4

This reviewer found that the thrust within the Powertrain Materials Core Program is an excellent example of how high-performance computational capabilities and expertise can be deployed to support a wide range of research and development efforts. The format can certainly help future VTO programs and, maybe more importantly, provide a framework for how this approach can be successful in other areas.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the efforts within this thrust are relevant largely because of the significant contributions to the other more applied thrust areas.

Reviewer 2

This reviewer pointed out that increased electrical conductivity, increased magnetic properties, and improved high temperature performance in electric vehicle propulsion components leads to downsizing, light weighting, and thus range-extending ability.

Reviewer 3

This reviewer said that all projects point to materials developments that improve energy efficiency.

Reviewer 4

This reviewer said that the work is relevant, since it is driven by needs of the other thrusts

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer found it difficult to quantify some of the efforts in this area, but the accomplishments indicate that the resources are providing an appropriate ability to support the needs of various programs from this thrust area.

Reviewer 2

This reviewer said that the resources appear sufficient for the project goals.

Reviewer 3

This reviewer said that the resources are reasonable.

Reviewer 4

This reviewer said that the team is very large and was not sure whether so many are needed.

Presentation Number: mat237
Presentation Title: Materials, Lubricants, and Cooling for Heavy Duty Electric Vehicles
Principal Investigator: Jun Qu, Oak Ridge National Laboratory

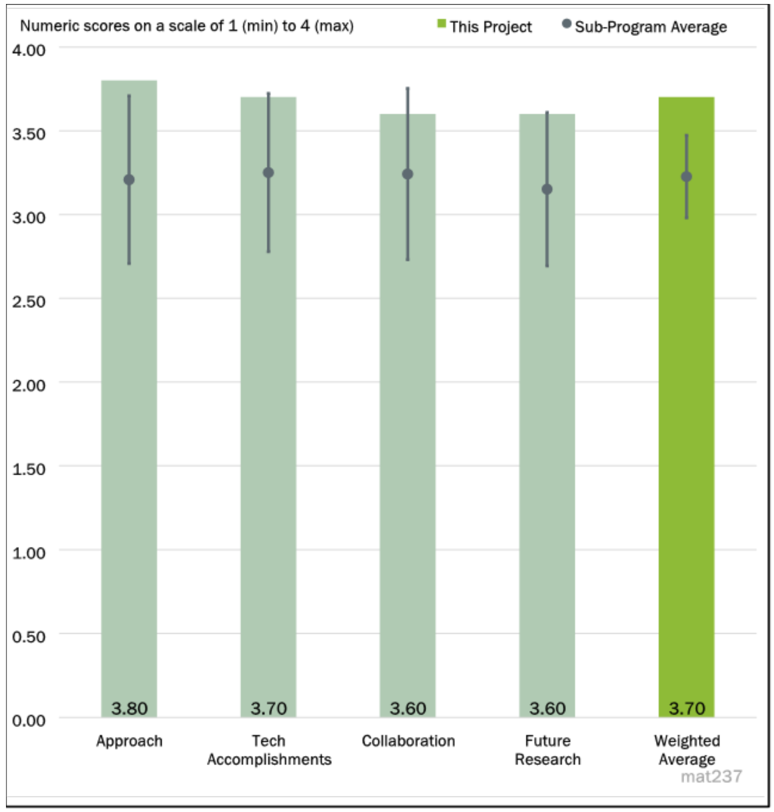

Figure 5-39 - Presentation Number: mat237 Presentation Title: Materials, Lubricants, and Cooling for Heavy Duty Electric Vehicles Principal Investigator: Jun Qu, Oak Ridge National Laboratory

Presenter

Jun Qu, ORNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer noted that the project aims at improving thermal conductivity and reducing the friction of the lubricants. The proposed approach is to add CNT to the lubricant oil. CNT is modified by adding ligands to make it compatible with oil, i.e., to suspend and disperse in oil. This project is creative. It properly addressed the technical barrier in thermal and frictional management in EV power train

Reviewer 2

This reviewer said that the need for thermal and frictional management in the electric vehicle space cannot be overstated. This is a critical space to allow success of future propulsion systems to thrive and decrease carbon emissions by society. According to the reviewer, the novel use of CNTs to address these two critical key issues is a great idea, and the issues are clearly addressed.

Reviewer 3

The use of CNT in lubrication is a novel approach, and depends on the organic molecule approach being effective. The sacrificial CNT coating is also novel. While it was mentioned that the coating could be used for lubrication OR for improved thermal transport, progress was only shown for its use for lubrication.

Reviewer 4

This reviewer said that CNTs show promise in thermal and lubrication properties improvement if they can be suspended in oil.

Reviewer 5

This reviewer found that the necessary pivot was made to support the new emphasis on EVs.

The team used existing knowledge from the ICME database to address issue encountered with EVs in regards to cooling and parasitic friction challenges. The reviewer believes that innovative basic science research is needed to understand the reaction of CNTs in lubrication fluids and their ability to improve cooling. This approach addresses two challenges with a single solution.

The reviewer believes that long term CNT suspension in oil will be the biggest challenge to overcome and if coating technology is not possible, it should be a focus going forward.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer found that the team has made good progress. For the lubricant task, CNT types were selected, about 7% increase in thermal conductivity has been demonstrated, and the modified CNT clearly shows evidence of suspending in lubricant oil. For the coating task, powertrain alloys for coating have been identified, CNT coating on Al has been demonstrated, and super-lubricity of coated CNT was demonstrated to be sustainable. The two proposed mechanisms explaining the origin of super-lubricity (CNT breakdown forming mini rollers and CNT/graphene coating by stress) are sound.

Reviewer 2

This reviewer believes the work of the team to identify and deploy the CNTs by selecting types and sizes for lubricants is a critical step to allow the next steps in this important research. The reviewer also believes that the identification of both a ferrous and a non-ferrous alloy for CNT coating is the correct approach in my view, as it allows this coating technology to be deployed in a wide range of EV applications.

Reviewer 3

This reviewer found that good progress has been demonstrated on steel and Al alloy selection and CNT surface coverage, along with good progress showing a 7-10% increase in thermal conductivities and initial success in oil suspension. Improved surface wear from sacrificial CNT coatings show super-lubricity for 27 hours.

Reviewer 4

This reviewer noted that initial trials showed a 7%-10% increase in thermal conductivity. CNTs allow use of thinner oil through improved lubrication by the CNTs. Organic modification improved suspension in oil, holding for 2 days and settling after 2 weeks. Super-lubricity was obtained (u less than 0.01) in micro scale sliding in an ambient environment and is hypothetically attributed to a CNT-induced graphene ultra-low friction surface film. It sustained ultra-low friction for 27 hours with only one droplet of oil.

Rapid CNT coating using chemical vapor deposition (CVD) showed some success at 600C or above, but below 600C, the CNT coating was unsuccessful.

Reviewer 5

This reviewer thought that the preliminary increase in lubricant thermal conductivity in PAG is encouraging. Improvement from treatment is encouraging. The reviewer believed that there is a need to study the lubrication properties of CNT coatings and their impact on thermal transport for parts that don't experience wear

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer said that significant interest from industry in this technology is being shown—cooperative research and development agreements (CRADAs) with Valvoline and industry project partners Ford and Honeywell demonstrate this interest. Ford, Tesla, and others are asking for this cooling capability.

Reviewer 2

This reviewer said that it is clear that the team is working well together and sharing ideas as well as tasks, given the extensive list of technical accomplishments

Reviewer 3

This reviewer said that the collaboration within ORNL resources was demonstrated and that external partners are showing strong interest in CRADAs.

Reviewer 4

This reviewer noted that ORNL plans to work with Valvoline, CRADA pending.

Reviewer 5

This reviewer said that the collaborations seem reasonable and more are underway.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the proposed work appears to be reasonable.

Reviewer 2

This reviewer found that the work proposed in both the coatings and lubricants space is clearly explained, and seems very relevant to the overall proposed tasks. The team has obviously collaborated well and has done a significant amount of research on the opportunity.

Reviewer 3

This reviewer opined that the planned coating below 575C is a good initiative for maintaining Al heat treatments while reducing friction. Quantitative characterization of CNTs' suspension and dispersion in oil is planned, as well as collaboration with CRADA partner for EV fluid requirements.

Reviewer 4

This reviewer stated that future research should continue to overcome the barriers encountered at the start of the project. Since CNTs are difficult to suspend in oil and graphene cannot be easily placed on surfaces since the orientation is difficult to control, research to address this challenge should continue. Research should also continue to determine the impact on material properties. Aluminum alloy was not the preferred metal to grow nano particles. A highly catalytic metal (Cr, Fe) is needed for the oxidation process, which should be investigated (and is planned),

The reviewer suggested that CNT life time should be extended. The deposition of CNTs on the surface increases lubrication. If the CNTs are destroyed, the thermal conductivity benefit will no longer occur. On Al, the CNTs are not destroyed, so thermal conductivity occurs.

Reviewer 5

This reviewer said that the future plans seem reasonable

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer observed that a lubricant that can outperform the current state of the art will dramatically impact on materials and system life. This technology will have large impact on many energy efficiency and renewable energy applications, including EV motor bearings, wind turbine bearings, etc.

Reviewer 2

This reviewer believes that the project could impact three of the thrusts: batteries, electrification, and energy efficient mobility systems. The reviewer stated that this work can make a significant difference in the adoption rate of electrification of vehicles by decreasing range anxiety and improving EV performance in non-optimum climates. This is the type of research that is essential to take EVs to the next level of adoption.

Reviewer 3

This reviewer said that increasing thermal conductivity and lubrication properties of oils allows for higher operating speeds, higher power density, reduction in friction losses, and light-weighting of EV drivetrains.

Reviewer 4

This reviewer stated that the project is directly relevant to the VTO Materials subprogram objectives.

Reviewer 5

This reviewer stated that the work is relevant

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer stated that the resources allocated to this project are appropriate.

Reviewer 2

This reviewer noted that clearly a lot of work was reported and data was provided. The resource needs are well documented and seem appropriate to the team size and expectations.

Reviewer 3

This reviewer said that funding appears sufficient for the initial goals and that CRADAs with industry partners should increase allocated funds.

Reviewer 4

This reviewer believed that the innovative approach to lubrication and cooling has significant commercial applicability in the EV space and throughout industry. This creative approach should continue and, if possible, be coordinated with other similar research efforts within and outside of DOE. Establishing a CRADA with Valvoline will increase the funding available for this research.

Reviewer 5

This reviewer believes that the funding level is fairly small but seems sufficient to complete the proposed work.

Presentation Number: mat238
Presentation Title: Advanced Processing and Additive Manufacturing for Electric Vehicle (EV) Propulsion, Ultra Conductor Development for Enhanced EV performance
Principal Investigator: Keerti Kappagantula, Pacific Northwest National Laboratory

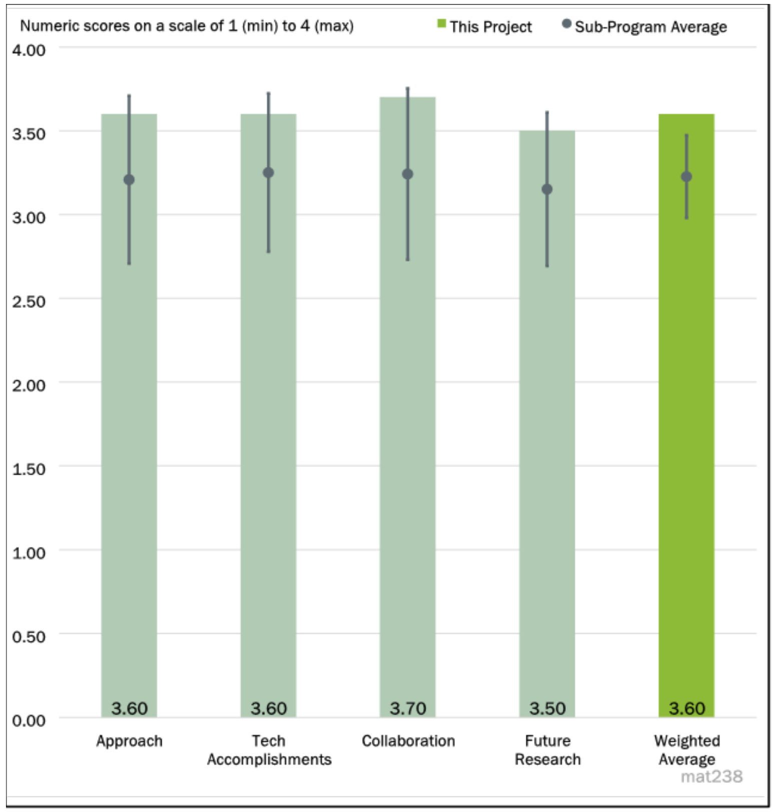

Figure 5-40 - Presentation Number: mat238 Presentation Title: Advanced Processing and Additive Manufacturing for Electric Vehicle (EV) Propulsion, Ultra Conductor Development for Enhanced EV performance Principal Investigator: Keerti Kappagantula, Pacific Northwest National Laboratory

Presenter

Keerti Kappagantula, PNNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer pointed out that the proposed approach is solid state processing. It uses a Cu-graphene mix as feedstock, processing it with shear-assisted processing, which is essentially friction induced consolidation and extrusion. The process can uniformly mix the two components and create intimate contact. The process can also create and manipulate extrudate texture.

Reviewer 2

This reviewer found that this project is well-designed and planned. The use of reduced graphene oxide in Al or Cu matrix to enhance conductivity is a clever route. The presence of a very small volume of oxygen in reduced graphene did not affect electrical properties. This material composition has good promise for scaled up manufacturing, which the industries need.

Reviewer 3

This reviewer noted that the project uses the ShAPE extrusion process to produce wire with low cost additives to make ultra-conductors. The project is tackling an important area to improve the electrical performance of current materials to allow for volume reduction of electrical motors in EVs. The reviewer finds that the approach to look at lower cost materials and a process with potential scalability is a good one.

Reviewer 4

This reviewer states that the project is attempting to create ultra-conductor materials with graphene additives through an advanced extrusion process. Metal feedstock and graphene in various forms is processed ShAPE apparatus at PNNL. Post processing, electrical and mechanical property measurements per ASTM B193 are conducted. The project is well designed and the timeline is reasonably planned based on the funding available.

Reviewer 5

This reviewer said that the investigators seem to be taking a reasonable approach.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer believed that the team made good progress. For the Al-graphene composite, about 7% improvement in conductivity has been achieved, and a 3 meter long uniform wire has been extruded; For Cu-graphene composite, an over 3 meter long uniform wire has been extruded. There are no results on conductivity improvement, however.

Reviewer 2

This reviewer observed that the project started nine months ago and has made significant progress. The reviewer likes the fact that high speed ShAPE processing makes the defects on wire surface disappear and asks whether it is the plasticity at high shear that helps to minimize surface defects.

Reviewer 3

According to this reviewer, the project has made good progress in producing samples. The project has found optimized process parameters and has created wire materials for testing. It is not clear from the results how closely the project is getting to its target of 10% improvement in conductivity or if that is the Go/No Go target.

Reviewer 4

Based on the planned milestones presented, this reviewer believes that the project is on schedule. This project has met two of its four quarterly milestones and is on track to meet quarter 3 and the quarter 4 go/no-go milestone.

Reviewer 5

This reviewer expresses concern regarding how long the wires can ultimately be made by this process. The reviewer states that it was never clear if large spools can be made as in traditional wire, despite his having asked the question. The reviewer suggests that it would be worthwhile to answer the questions of, what the end product would look like and how it would be used. It could be that the wires made would be long—but not huge spools that are currently made. The reviewer believes that it would be good to clarify this point.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer said that PNNL works closely with ANL on microstructural analysis of the extrudate. Quarterly meetings were carried out with industrial partners.

Reviewer 2

This reviewer found that the project has a great team and good collaboration between different thrusts within the program. ANL, ORNL and PNNL together are doing a great job.

Reviewer 3

This reviewer noted that the project team is meeting with the advisory panel on a quarterly basis which seems sufficient.

Reviewer 4

This reviewer pointed out that the project team is led by PNNL with participation from Ohio University and Argonne National Laboratory and industrial partners Hydro Extrusions and Rolls Royce. It appears that the bulk of the effort is being conducted by PNNL with consulting by ANL, Ohio, and Hydro Extrusions. Argonne National Lab is supporting the project on Al/graphene and Cu/graphene composites to characterize microstructure. PNNL holds monthly meetings with Argonne to review the status of the work. Quarterly meetings are held with Hydro Extrusions and Rolls Royce.

Reviewer 5

This reviewer believed that the collaborations are excellent, but strengthening the ties to multiple motor design groups might be advantageous. (The PI is already working with at least one group.) Actually, the PI may want to consider establishing formal ties to the VTO motor design group led by ORNL and which includes Purdue, University of Wisconsin, Illinois Institute of Technology, and North Carolina State.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the proposed work appears to be reasonable, suggesting that the team add a task for a feedstock powder quality study, e.g., oxygen level, impurities, etc.

Reviewer 2

This reviewer said that the team is ready to demonstrate scalability with manufacturing of the materials and that it should stick to that plan.

Reviewer 3

This reviewer noted that the future work for this project includes enhancing composite performance through process and composite chemistry variation and determining the effects of post processing techniques on the performance of the ultra-conductors. Understanding the variables involved in processing of the ultra-conductors with the ShAPE extruder will be important to maximizing electrical properties of the materials. The reviewer believes that this team is well qualified to approach these variables with expertise in material design, electrical property measurement, and microstructural characterization. The reviewer suggests that in the longer term, if successful materials are developed, testing in an electric motor design to prove the concept would be ideal.

Reviewer 4

This reviewer opined that what the PI set forth as a plan makes sense, but it was at a very high level.

Reviewer 5

This reviewer said that the proposed work is important but that it would also be good to see some work around process repeatability and robustness.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer believes that a conductor more conductive than Cu will have direct impact on many energy efficiency and renewable energy applications. The proposed Cu-graphene composite is definitely a promising approach.

Reviewer 2

This reviewer said that the project is very aligned with VTO objectives.

Reviewer 3

This reviewer believes that the U.S. DRIVE Partnership and the Electrical and Electronics Technical Team have identified the reduction in volume of electric motor components as an enabling technology. According to the reviewer, this project, if successful, would increase the flux density capabilities of electric steels and the electrical conductivity of Cu windings, both of which would enable motor volume reductions by necessitating fewer materials. Increases in conductivity could potentially increase overall motor efficiency and reduce motor volume.

Reviewer 4

This reviewer said that the project is aligned with the new materials development goal for vehicle electrification.

Reviewer 5

This reviewer believes that this project is extremely relevant. Obtaining better conductivity, a lower temperature coefficient of conductivity, and high thermal conductivity makes a huge and ubiquitous difference in machine design. The reviewer approves that the project is considering both Cu and Al enhancement.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the resources allocated to this project are appropriate.

Reviewer 2

This reviewer believes that, since the project is using existing working equipment to produce the samples and a known ASTM standard for testing, the resources appear to be sufficient to complete the milestones. According to the reviewer, no major barriers seem to be apparent.

Reviewer 3

This reviewer pointed out that the project is funded at $500,000 per year for 2 years and believed that this amount is sufficient to cover the initial phase (2 years) of research on Al and Cu ultra-conductor extrusions with the ShAPE machine and conducting modeling and testing of the results.

Reviewer 4

This reviewer stated that the resources are sufficient.

Reviewer 5

This reviewer said that it would seem that the resources are adequate.

Presentation Number: mat241
Presentation Title: Advanced Processing and Additive Manufacturing for Electric Vehicle (EV) Propulsion, Advanced Ceramics and Processing for Wireless Charging Systems
Principal Investigator: Beth Armstrong, Oak Ridge National Laboratory

Presenter

Beth Armstrong, ORNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

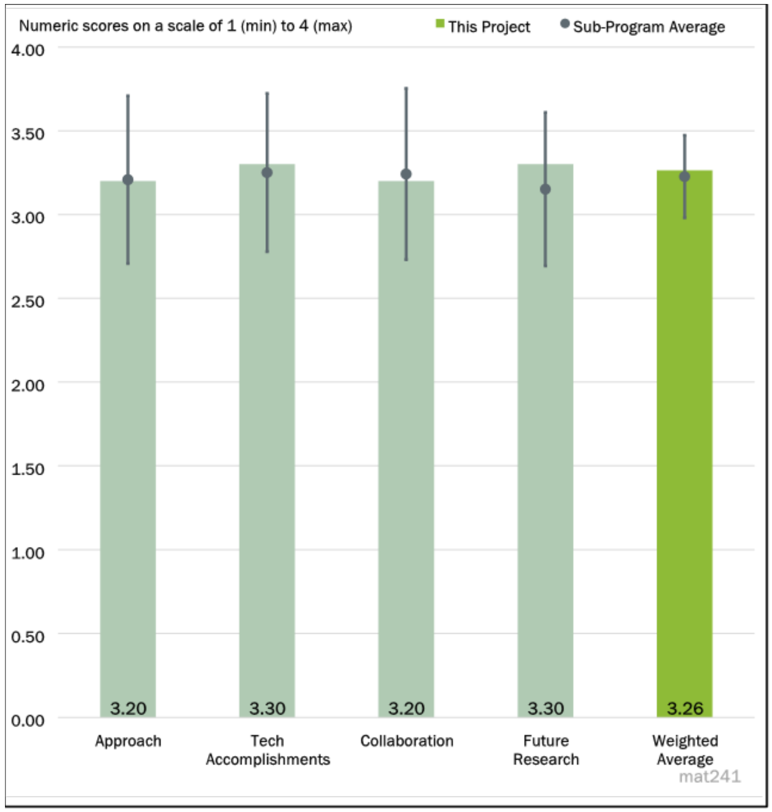

Figure 5-41 - Presentation Number: mat241 Presentation Title: Advanced Processing and Additive Manufacturing for Electric Vehicle (EV) Propulsion, Advanced Ceramics and Processing for Wireless Charging Systems Principal Investigator: Beth Armstrong, Oak Ridge National Laboratory

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer believes that the PI is doing a good job, program is well designed, but has quite a lot on her plate. US DOE VTO changed from ICE to BEVs quickly and the Materials team had to scramble to find appropriate programs/PIs to enlist on this subject.

Reviewer 2

This reviewer noted that an extensive literature search has been completed on smaller scale systems. The PI acknowledged that prior modeling efforts could have avoided some exploration of unfruitful compositions but was out of scope due to time and budget constraints.

Reviewer 3

This reviewer believes that, overall, the project is attacking an interesting problem. The approach for down-selecting the material is very good and an excellent use of ICME techniques. It is not clear from the presented material, however, how scalable the actual processing method is. That is an important consideration and the equipment availability challenge could be a major obstacle that will influence the Go/No Go decision. The reviewer questions whether an industry or other partner would be helpful for this. Also, the Go/No Go milestone doesn't seem well defined.

Reviewer 4

This reviewer said that the approach provides a pathway for addressing the technical barriers to using ceramics in wireless charging for lighter weight and more efficient systems. This project aims to develop tunable and lighter weight advanced ceramic materials and processing methods for fabrication of wireless charging systems for EVs. The approach covers various steps needed to go from determining material properties of interest to optimizing ferrite fabrication methods.

Reviewer 5

This reviewer noted that a wireless charging system involves a roadway component and a vehicle component and asked whether light weight really comes to play on the roadway component of the magnetic core. It seemed to the reviewer that two different materials may be needed.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer said that the project appears to have made good progress on the first two tasks, which were the literature survey and the determination of initial down-select parameters.

Reviewer 2

This reviewer found that significant progress has been made on the screening protocol development, which is critical to baselining chemistry and material availability. He noted that doped ferrites seem to be a promising candidate material. Grain alignment and sintering are important fabrication elements.

Reviewer 3

This reviewer said that the project appears to be hitting milestones as per plan. Candidate materials have been identified for further exploration.

Reviewer 4

This reviewer said that progress seems on track, but the critical step of the first iteration of material is still in progress.

Reviewer 5

This reviewer found that the most important technical progress was the spinel ferrite (AFe_2O_4) using A-site doping for better tunability. The team's fabrication used either 1, 2, or 3 elements, then down selected to Binary $Ni_{0.5}$ / $Zn_{0.5}$/Fe_2O_4. The team wanted to use more modeling but the existing models are not adequate to predict magnetic properties.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer noted that the project is in the early stages so currently collaboration efforts are appropriate. The participants may want to involve others as the processing techniques are further refined.

Reviewer 2

This reviewer suggested that it would be good to drive collaboration and show alignment to other DOE wireless charging projects, particularly ELT262 "Long-Range Battery Electric Vehicle with Megawatt Wireless Charging" where large chillers were required to keep ground coils cool. The reviewer asked if higher temperature ceramics could provide value here.

Reviewer 3

This reviewer said that there had been good collaboration during fiscal year 2022 among ORNL as the lead lab (utilizing National Transportation Research Center and Manufacturing Demonstration Facility resources), Steward Advanced Materials (providing commercial powders), the VTO Grid and Infrastructure team, and the Basic Energy Sciences-Material Sciences and Engineering Division.

Reviewer 4

This reviewer said that it seems like a good team, though one could make the case that including some collaborators outside of the national lab might be useful just to gain another perspective.

Reviewer 5

This reviewer said that there had been good collaboration between national labs and industry but that the team could also use university partners to advance the database/modeling portion (Thrust 4).

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the next phase will be looking at shear formation/grain alignment and whether fabrication should be by resin or slurry.

The reviewer stated that morphology for shape, the surface change in front of shear

The reviewer stated that the team should possibly look at selective laser sintering or different types of AM.

Reviewer 2

This reviewer said that the development and refinement of the measuring techniques will be an important next step. The development of the colloidal processing (and sintering) should also include work that will help to translate to scalability, including the manufacture of larger structures.

Reviewer 3

This reviewer said that the project shows good foundational research plans to develop large scale ceramic material processing for wireless chargers.

Reviewer 4

This reviewer said that the proposed future research and development of magnetic testing techniques and colloidal processing techniques will help address inadequate models and limited literature on this subject.

Reviewer 5

This reviewer said that the plan seems to make sense but a little more detail would be nice.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the approach to EVs having to re-charge while in use is interesting but the reviewer is not sure how robust system will be required.

Reviewer 2

This reviewer noted that dynamic charging or wireless charging developments will further the acceptance of EVs because of the passive nature of the charging.

Reviewer 3

This reviewer noted that the project is part of the VTO Powertrain Materials core program as part of Thrust 3 (advanced and additive manufacturing for EVs), as it addresses the advanced ceramics and processing for wireless charging systems (ferrites).

Reviewer 4

This reviewer believed that ceramics provide more flexibility to tune magnetic performance than metallics. Ceramics also provide greater light-weighting capability, which will be key for the vehicle side of the system. The reviewer noted that the PI acknowledges that final solutions may involve hybrid metallic/ceramic materials.

Reviewer 5

This reviewer felt that dynamic charging is an engaging target in the EV world, so this is very relevant. The reviewer also believed that adding structural considerations of material in a roadway would be something to consider.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the project was making good use of limited data/resources.

Reviewer 2

This reviewer said that, because this is a low TRL project, current resources seem sufficient.

Reviewer 3

This reviewer said that the $290,000 allocation seems appropriate for the fiscal year 2022 budget (this is a 3-year effort that started in 2021).

Reviewer 4

This reviewer believed that the resources are sufficient.

Reviewer 5

This reviewer believed that the new Magneto-rheology tools are needed to measure in-situ processing to help develop techniques. Predictive chemistry models are also requested to facilitate efficient experimental use. These will likely require funding expansion.

Presentation Number: mat242
Presentation Title: Advanced Processing and Additive Manufacturing for Electric Vehicle (EV) Propulsion, Novel Ultra High Conductivity Composites for EVs
Principal Investigator: Tolga Aytug, Oak Ridge National Laboratory

Presenter

Tolga Aytug, ORNL

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

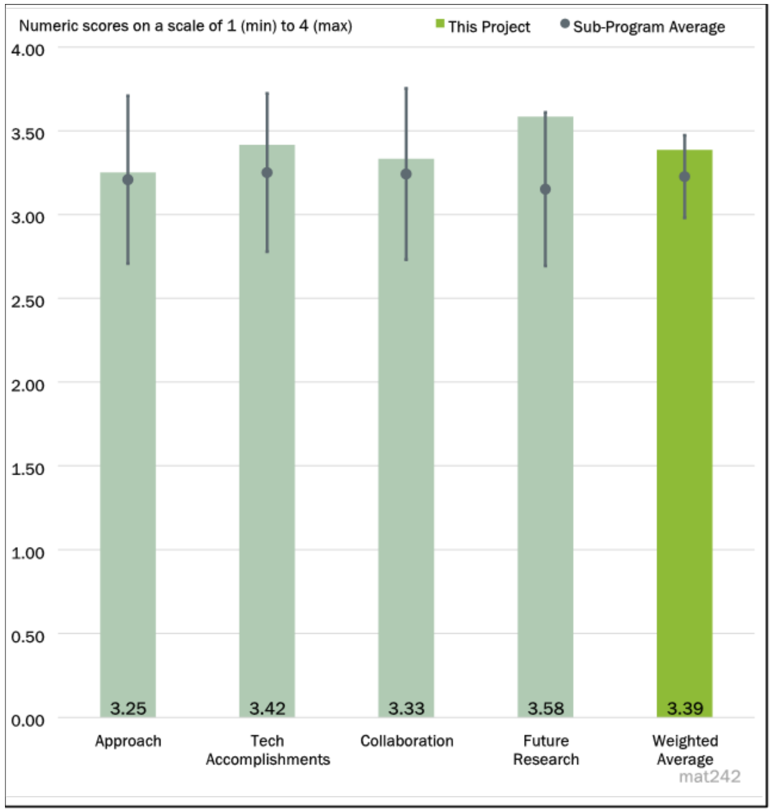

Figure 5-42 - Presentation Number: mat242 Presentation Title: Advanced Processing and Additive Manufacturing for Electric Vehicle (EV) Propulsion, Novel Ultra High Conductivity Composites for EVs Principal Investigator: Tolga Aytug, Oak Ridge National Laboratory

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that the U.S. DRIVE Electrical and Electronics Technical Team and Materials Technical Team roadmaps have identified reductions in electric motor components volume and weight to meet DOE 2025 power density, size, and reliability targets. Electric motor efficiency can be limited by electrical conductivity of the Cu windings. The USDRIVE roadmaps call for new advanced materials with improved capabilities and performance. Specifically, the Materials roadmap calls out carbon-nanotube based Cu materials as a key enabler.

This project proposes to develop high-performance Cu conductors using carbon nanotubes that are higher in electrical conductivity, current carrying capacity and mechanical strength. This directly addresses the technical barriers laid out in the project plan.

This is a new project and the development of the Cu-based tapes are still in process. ORNL has been completing modeling, and theoretical and computational studies of the complex parameters prior to scale-up of CNT deposition. Following CNT deposition, the project will refine and complete optimization of the process. Analyzing the processes and sensitivity to material properties and system parameters.

Reviewer 2

This reviewer noted that the project aims at improving conductivity of electric conductors. The proposed approach of making Cu-CNT composite is adapted from the high temperature superconducting wire process, it has three steps: deposit CNT, then deposit Cu, then anneal. The CNT electrospinning with polyvinylpyrrolidone (PVP) produces orientated fibers, which is key to the conductivity improvement.

Reviewer 3

This reviewer believed that the work is an important analysis of a novel technique to improve the conductivity of Cu tape using composite stacks and the researchers have shown some strong performance results. The project would be improved with more attention to robustness/consistency of the process and cost as compared to current process, in addition to optimizing performance. Overall, the reviewer considers it a strong project.

Reviewer 4

This reviewer said that the PI is doing a good job, bringing his advanced physical and chemical vapor deposition approaches as well as advanced materials characterization skills to the table. The program is well designed. The timing is too short to achieve 2025 advanced materials target.

Reviewer 5

This reviewer recognized the benefits of CNT deposition on a tape substrate, but questions whether a highly conductive Cu tape has a viable path to commercialization in EV powertrains and off-board charging equipment relative to the widely applied round product. The reviewer also asked what barriers exist to implementation of a tape vs round product. The reviewer believes that the mechanical strength of a round profile in bending and tension is superior to a rectangular tape with inherent stress risers, thus possibly negating any added mechanical strength benefits.

Reviewer 6

This reviewer noted that this effort is about ultra-conducting copper (UCC) composites, which are of very high interest in the electrical machinery universe. The reviewer said that the PI has produced material which is impressive.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer believed that the team made good progress. The resulted improvement in conductivity and ampacity were 6% and 15%, respectively. Perhaps more interesting for future improvement, he ORNL team found that nitrogen doping may improve electron density of CNT.

Reviewer 2

This reviewer noted that the PI has produced UCC tape, which the reviewer says is the key to the effort.

Reviewer 3

This reviewer believed that the project has demonstrated a considerable improvement in electrical properties with the addition of CNT in a short period of time. The project appears to be on track to address some of the major issues.

Reviewer 4

This reviewer pointed out that this is the first year of this project. ORNL has completed their first 2 quarterly milestones. Establishing critical design inputs for a single layer Cu-nanotube prototype and theoretical and computational studies. In the second half of the year, it will be establishing key processing needs, setting up tools for scale up of CNT deposition, and refining and completes optimization of the processing steps.

Reviewer 5

This reviewer said that the project achieved a good improvement of 10% decrease in resistivity and a greater than 20% increase in ampacity on Cu foils by embedding CNTs

Reviewer 6

The reviewer said lack of understanding parameters and microscale performance/nitrogenated. It was interesting that the nitrogen signal –4 different conditions which was attributed to CNT materials. 1/3 metal (good) + 2/3 semi conducting (bad).

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer pointed out that ORNL works with several companies including wire manufacturer southwire and materials provider General Graphene.

Reviewer 2

This reviewer noted that suppliers are providing materials and Southwire, as a project partner, shows interest from industry in the work.

Reviewer 3

This reviewer said that the project is collaborating with industry partners, which is important for the transfer of the process and addressing the industrialization of the process.

Reviewer 4

This reviewer noted that the project is led by ORNL with partners Southwire, Chasm Advanced Materials, and General Graphene. The bulk of the work is being completed by ORNL with material support from the other partners. As the project develops and if initial phases are successful, it would be beneficial to see CNT-Cu wires used in real work applications at ORNL or with additional industry partners.

Reviewer 5

This reviewer believed that, while collaboration has been good, the project team could be improved by having some meetings with the ORNL lead electric machinery group (Sandia, Purdue, University of Wisconsin, Illinois Institute of Technology, and ITT, North Carolina State).

Reviewer 6

This reviewer found good Industry collaborations, which were critical to establishing a reliable process, but the team could also use possible additional collaboration(s) to help with scale up to commercial high temperature superconducting wire process

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the proposed work appears to be reasonable.

Reviewer 2

This reviewer said that the future research does include investigating and optimizing repeatability, which is extremely important. Overall, the plan seems sound for addressing the barriers identified.

Reviewer 3

This reviewer found that the project has a clear strategy towards commercial viability for ultra-conducting Cu. The project has developed a new process for fabrication of ultra-conducting Cu. The team is currently in the process of optimizing the fabrication process to achieve high microstructural quality prototypes. It will explore prototypes with various parameters and properties to optimize electrical and mechanical properties. Future work will also include developing tools for scalable roll-to-roll assembly of ultra-conducting Cu composites. In the longer term, it would be interesting to see collaboration with ORNL electric motor and power electronics developers utilizing this technology.

Reviewer 4

This reviewer believes that developing an optimized CNT process solution for tape form is a good foundation. If round vs rectangular tape profile concerns are shared by Southwire, it would be good to outline a future path to a round UCC solution.

Reviewer 5

This reviewer state that the future plan is a bit more specific than others the reviewer has seen, and the reviewer believes that the effort looks well focused.

Reviewer 6

This reviewer noted the use of IA to look at additional layers to achieve long length UCC greater than 50 cm.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer opined that the UCC materials 10 cm in length are nice in the lab but that the timeline is not long enough to be able to address the 2025 ultra-high conductivity materials target for vehicles because making carbon nanotubes work for this application is no small task.

Reviewer 2

This reviewer believed that a conductor more conductive than Cu will have direct impacts on many energy efficiency and renewable energy applications. The proposed Cu-CNT composite is definitely a promising approach.

Reviewer 3

This reviewer said that the project is attempting to address material solutions to improving efficiency in EV systems and also addressing some of the sustainability challenges around Cu. So it fits well with the VTO goals.

Reviewer 4

This reviewer stated that the project is directly relevant to the Electrification and Materials sub-programs at DOE. This project has theoretically shown the potential for remarkable improvements in electrical properties over pure Cu. These improvements in electrical properties will have a direct impact on the volume, power density, and efficiency of electric drive technologies.

Reviewer 5

This reviewer believes that greater efficiency in electric conduction will improve power density and reduce weight for electric drive system components. There is potential for this project to also reduce Cu requirements on future EVs, which are expected to surge.

Reviewer 6

This reviewer said that UCC very much supports the VTO program objectives. and believes that it should be used in electric machine designs.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer found good use of resources and is looking forward to seeing future work on how additional Cu/CNT layers on the structural and electrical properties of UCC prototypes.

Reviewer 2

This reviewer said that the resource required by this project is appropriate.

Reviewer 3

This reviewer said that the resources should be sufficient in conjunction with support of the industry partners for manufacturing samples.

Reviewer 4

This reviewer said that the project funding and resources are sufficient for the proposed level of effort in the first 2 years of this project. If that work is successful, additional resources could be needed to continue testing of samples or incorporate CNT-Cu conductors in electric drive technologies components to verify the utility of this technology.

Reviewer 5

This reviewer said that the resources appear sufficient.

Reviewer 6

This reviewer did not feel completely qualified to answer the question but believed that the resources are sufficient.

Presentation Number: mat243
Presentation Title: Manufacturing Demonstration of a Large-scale, Multi-material Passenger Vehicle Sub-system
Principal Investigator: Srikanth Pilla, Clemson University

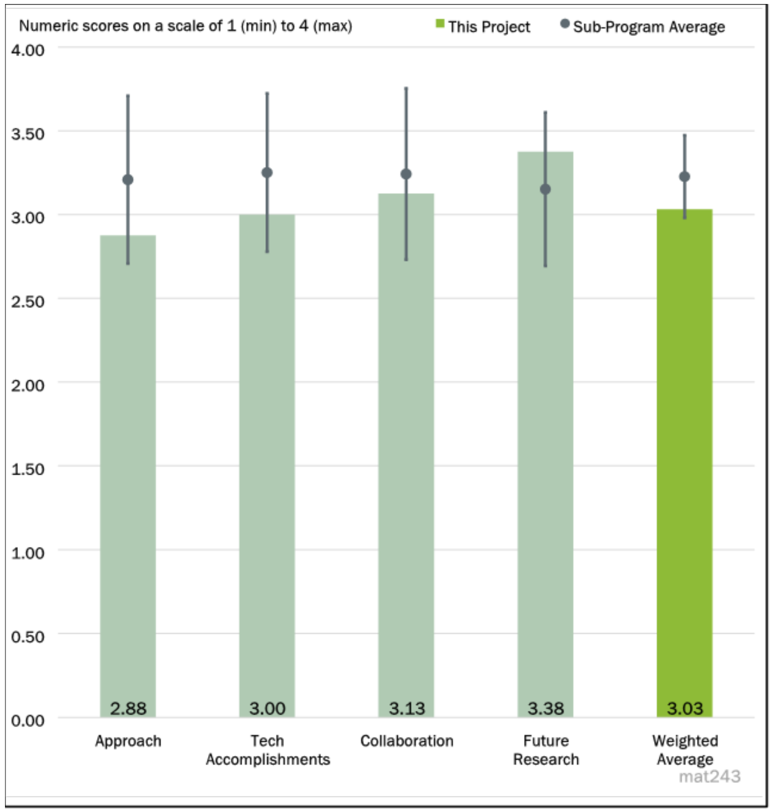

Figure 5-43 - Presentation Number: mat243 Presentation Title: Manufacturing Demonstration of a Large-scale, Multi-material Passenger Vehicle Sub-system Principal Investigator: Srikanth Pilla, Clemson University

Presenter

Srikanth Pilla, Clemson University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer believes that this is an innovative and comprehensive approach. The reviewer found it less science-based than many of the other programs, but good training for students and good sources of new ideas for all partners.

Reviewer 2

This reviewer stated that the barriers to achieving the project goals are not technical barriers per se. If technical barriers are to be considered, then there should be specific consideration to the manufacturing readiness level of the wet compression molding process and development of the transition joint. The project per se, is well designed to investigate the overall vehicle concept and construction in order to achieve mass savings.

Reviewer 3

This reviewer said that the ultrasonic additive manufacturing (UAM) is unique in bonding metals with carbon fiber reinforced thermoset composites. This is the first year of the project. The presented approaches are listed at high level and comprehensive. The reviewer suggested that possibly go/no-go strategy could be given according to the proposed tasks.

Reviewer 4

This reviewer said that, although the project identifies an OEM partner (Honda), review of the presentation does not give any indication of what the OEM will be doing in the project and leaves this reviewer with the impression that the OEM will not be involved sufficiently to ensure a successful project, in fact, leaving the design and analysis work to be conducted by Clemson University students instead of more experienced OEM engineers and designers.

The technology development and validation is too extensive for application on a complete vehicle glider system at this time and should be validated on a much smaller project before being applied to one of this scope. The processes being proposed do not appear suited for some of the complex shapes required of a full vehicle glider system at this time, including, as an example, a body side aperture (especially the b-pillar), with numerous contour changes in all three dimensions. The project should be focused on developing and validating one or two complex sub-assemblies with the UAM process rather than developing a full vehicle glider system at this time. The reviewer said that no go/no-go points are identified anywhere in the presentation.

According to the reviewer, the joining process complexity of CF to steel, as proposed in the project, as well as the high cost of CF (even recycled CF), make it unlikely that this project will meet VTO cost objectives.

The reviewer believes that vehicle recycling (not just CF recycling) will be virtually impossible (at the very least unaffordable) with this concept since the CF components will have to be separated from the steel flanges before the glider can be recycled.

The reviewer said that the project really appears to be focused more on development and evaluation of new CF material technologies and new joining processes than on developing a light-weight vehicle glider system, which should be investigated after these technologies have been proven on smaller scale subsystems.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer believes that the team has accomplished the proposed tasks completely in the first two quarters.

Reviewer 2

This reviewer believed that, although it is early in the whole process, the team seems to be on track.

Reviewer 3

This reviewer said that the reported progress seems to be in line with expectations for a project kicked off only six months ago.

Reviewer 4

This reviewer said that, because the project has just begun, it is premature to evaluate this.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer stated that the program brings together a large comprehensive team with great partners.

Reviewer 2

This reviewer pointed out that the team is composed of ten partners, which include the technical know-how to make the project successful, except for the fact that the team does not have a molding partner to provide the technical and cost input for the wet compression molding process. The project needs to have a plan in place to secure this gap. This will be critical to the business case when considering annual volumes of 200,000 vehicles.

Reviewer 3

This reviewer found that the team is well formed, including collaborators from university, an OEM, global n-tier partners, and recycling partners. However, the role or associated tasks of each partner are not very clearly presented in this presentation.

Reviewer 4

The reviewer believed that the overall list of collaborators appears well suited to developing CF composite intensive structures. However, according to the reviewer, there is little evidence of the type of expertise necessary to fully design, build, and validate a full vehicle glider system, with the exception of the OEM, which does not appear to be involved to the extent necessary for this project to achieve its stated goals (at least in the design and analysis, which are being conducted by Clemson University students).

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer found that the team had put forward an excellent plan And is looking forward to their achievements.

Reviewer 2

This reviewer said that the future research is comprehensive and aligns well with the proposed milestones. The proposed work should address the challenges and barriers.

Reviewer 3

This reviewer said that the proposed future work is focused on meeting some of the needs to ultimately develop a CF/steel multi-material glider system, although more actual physical validation of the transition joints should be conducted prior to starting the multi-material glider optimization.

Reviewer 4

The project is well thought out in a logical sequence. The only point that I would add is that the cost analysis needs to consider not only the cycle time but also the investment which would be required to achieve a volume of 200,000 vehicles/year.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer answered that the project is centered around enabling mass reduction at minimum disruption to existing infrastructure. Mass reduction is an integral component of the DOE target of reducing greenhouse gas emissions.

Reviewer 2

Innovative manufacturing belongs in the DOE portfolio.

Reviewer 3

This reviewer believed that the joining of dissimilar materials is a critical area in advanced manufacturing for DOE to reduce the structural weight and improve component performance and energy efficiency.

Reviewer 4

This reviewer found that the project proposes to develop a multi-material vehicle glider to achieve a 160 lb. (73 kg) weight reduction with no compromise on performance targets, at a cost increment of no more than $5 per pound saved, at a production volume of 200,000 vehicles per year, using recycled carbon fiber. This clearly is relevant to stated VTO subprogram objectives, although the likelihood of achieving the VTO cost objectives is poor.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

Without an understanding of the in-kind and cost allocation, it is difficult to make an informed comment here. Although the total project is $11.5M, there will be significant analysis time, coupon testing, and component fabrication. However, given that Honda has significant experience in vehicle program development I would assume it has a good handle on the resources required to achieve their goals.

Reviewer 2

This reviewer said that the budget should be able to carry out the tasks described.

Reviewer 3

This reviewer said that the team has sufficient facilities, expertise, and human resources to achieve the stated milestones.

Reviewer 4

This reviewer believed that the budget of $11,500,000 should be sufficient if the work is conducted efficiently. However, the timeline of slightly more than 3 years is likely to be insufficient, given the number of new technologies being investigated, developed, and proven(transition joint process and recycled CF properties) before serious design and analysis of the glider can be considered. Additionally, more involvement from the automotive OEM will likely be required in order for this project to achieve its stated goals.

Presentation Number: mat244
Presentation Title: LMCP P1A - Sheet Materials with Local Property Variation
Principal Investigator: Scott Whalen, Pacific Northwest National Laboratory

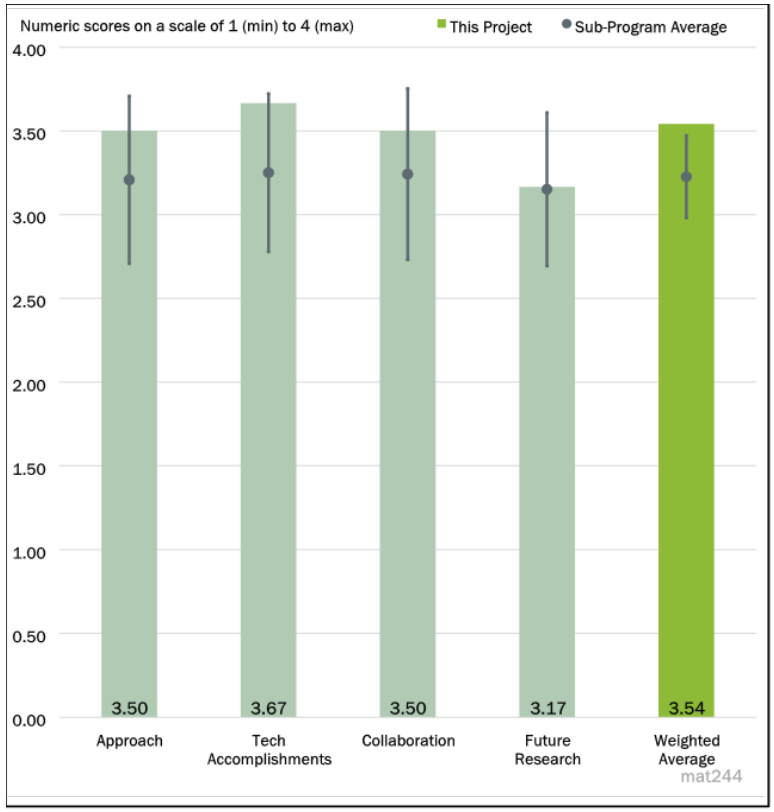

Figure 5-44 - Presentation Number: mat244 Presentation Title: LMCP P1A - Sheet Materials with Local Property Variation Principal Investigator: Scott Whalen, Pacific Northwest National Laboratory

Presenter

Scott Whalen, PNNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The technical barriers that are being addressed are well defined and the project is set up with clear milestones designed to advance the ShAPE approach in the context of manufacturing of Al tube and strip.

Reviewer 2

The shear extrusion process is used to test the ability to produce Al tubes with variable thickness. Eventually these tubes will be sectioned to produce strips which can be used similar to tailor weld blanks for sheet forming; the validity of this approach is questionable but obtaining tubes with variable wall thickness and properties could be useful for some applications.

Reviewer 3

The project is clearly defined with clear milestones to address the barriers. There is no modeling component , but the PI mentioned that there is collaboration with another project as far as the modeling is concerned. It would be useful for a connection with these efforts to be made and to see the contributions from modeling.

Reviewer 4

The shear extrusion process is used to test the ability to produce Al tubes with variable thickness. Eventually these tubes will be sectioned to produce strips which can be used similar to tailor weld blanks for sheet forming; the validity of this approach is questionable but obtaining tubes with variable wall thickness and properties could be useful for some applications.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The program appears to be on track to complete the planned milestones for this FY. This has included notably the successful completion of the design of the variable wall extrusion system, and demonstration of the extrusion of Al 6082 with T6 properties using T5 heat treatments, consistent with the first two milestones.

Reviewer 2

Shown the usefulness of the process to produce variable wall thickness and/or property enhancements. The process parameters such as feed, speed were varied and their impact on performance is validated.

Also possibility of producing composite material tube is explored. Recyclability of this material will be a problem but the technology can be useful in certain applications.

Reviewer 3

The project plan is on track. Multi alloy extrusion has been achieved. Mechanical properties tuning has been demonstrated. The variable wall thickness goal is on track.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer found that, given the progress of each of the tasks assigned to each of the team members at PNNL, collaboration within the team seems to be well managed. The PIs are encouraged to enhance the collaboration with industry to continue to guide the process design in a way that will enable the research to have maximal impact.

Reviewer 2

This reviewer said that the material supplier, research lab, and end user are actively involved in this project, making the knowledge dissemination easier.

Reviewer 3

This reviewer said that the collaboration between the lab and the industry partners is clear. Their roles are well defined and the synergy seems very effective.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the proposed work appears to be well designed to address the remaining identified barriers and challenges. The reviewer suggested that it would be helpful to understand the degree to which the ICME approaches being developed in the cross-cutting LMCP project could be used to guide the process design as the work evolves to consider other materials systems.

Reviewer 2

This reviewer said that the project's future work is well defined and connected directly to the remaining barriers. Some goals have been achieved earlier than planned. The project's targets are likely to be achieved on time. The reviewer believed that it would be useful to see the connection with or contributions from modeling, which is being performed in collaboration with another project.

Reviewer 3

This reviewer pointed out that a structure with variable wall thickness and/or variable property limits will react to uniform loads differently than monolithic material. The reviewer questioned what the design criteria are for using such a structure and suggested that a design and test approach is needed to confirm that this is a safe process.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the work is developing a methodology of locally modifying properties during extrusion processes and is consistent with the goals of the LMCP to develop scalable, cost effective processing methods to locally enhance the properties of Al and Mg in order to enable broader implementation of light-weight alloys.

Reviewer 2

This reviewer believes that light-weighting is an enabler to improve energy efficiency or range in vehicles. Aluminum can be used to reduce the weight of vehicles. The using less energy intensive manufacturing processes and air cooling to achieve T6 properties can reduce the carbon and energy footprint of the material as well.

Reviewer 3

This reviewer found that the project supports the subprogram's objectives. The project supports the need for light-weight materials and for environmental gains in vehicle manufacturing processes.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that an important development was the design and the procurement of the components to develop the variable wall extrusion system, which will provide a necessary resource for the future work.

Reviewer 2

This reviewer said that the resources are adequate.

Reviewer 3

This reviewer said that the resources seem sufficient for completing the work.

Presentation Number: mat245
Presentation Title: LMCP P1B - Form-and-Print - AM for Localized Property Enhancement of High-strength Al sheet
Principal Investigator: Alex Plotkowski, Oak Ridge National Laboratory

Presenter

Alex Plotkowski, ORNL

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

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

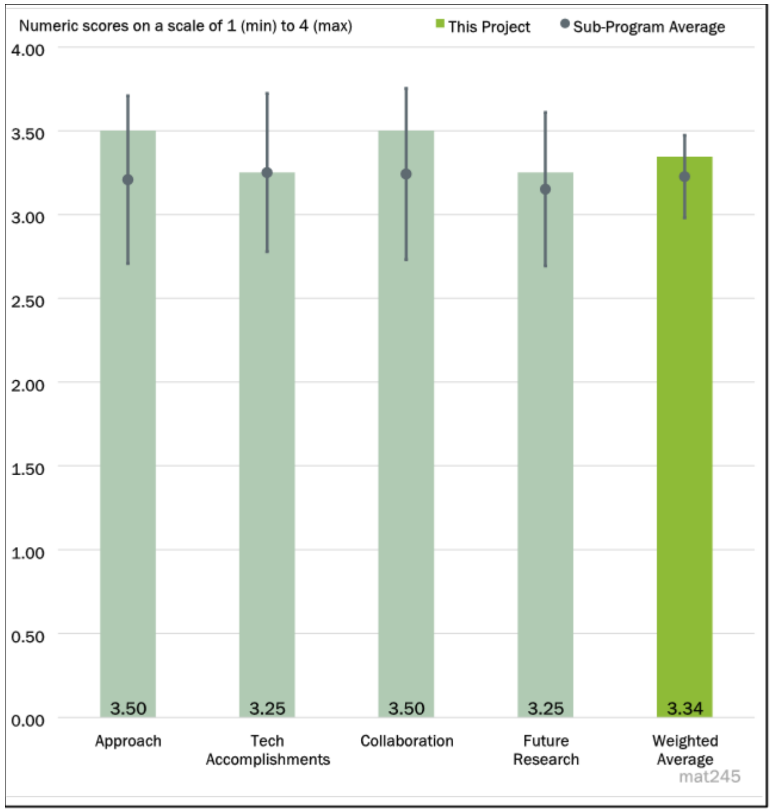

Figure 5-45 - Presentation Number: mat245 Presentation Title: LMCP P1B - Form-and-Print - AM for Localized Property Enhancement of High-strength Al sheet Principal Investigator: Alex Plotkowski, Oak Ridge National Laboratory

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that the project is a novel investigation exploring a wide open space of opportunity to align and integrate additive manufacturing into automotive design and production.

Reviewer 2

This reviewer said that the project is testing AM techniques to add/modify local features and microstructures to enhance performance of Al sheets. This is more of a fundamental study than an application, suitable for the lab funded project. All aspects of the work are being planned, including alloys, process variables, and characterization. One aspect missing is long term performance testing, such as corrosion and fatigue.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer said that progress has demonstrated that fundamental opportunities exist and warrant exploration.

Reviewer 2

This reviewer noted that the team has developed an equipment and tested it for operation and has completed various alloy depositions and conducted testing. The reviewer said that it has developed models on the depositions, air flow, and other aspects of the process. The knowledge generated will be useful for further understanding of the laser deposition process.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer said that the team has made strong efforts to communicate with industry and to use industrial perspectives to inform the development plan. The reviewer disclosed that he participated in this industrial engagement.

Reviewer 2

This reviewer reported good integration with other labs and that an equipment supplier and OEM are involved in advisory roles.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer found that the future workplan considers relevant materials, manufacturing roadblocks, and timely topics in the area of sustainability.

Reviewer 2

This reviewer suggested that long term exposure tests could be incorporated into the tasks

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 3

This reviewer believes that the project is aligned with VTO’s objectives and seeks to explore a topic not previously investigated by industry or university in a meaningful way.

Reviewer 4

This reviewer believes that increasing the performance of Al sheets can make them more attractive for enclosures and this will make light-weighting of the vehicle easier.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the project’s resources appear to be appropriate and sufficient to accomplish objectives.

Presentation Number: mat246
Presentation Title: LMCP P1C - Local Thermomechanical Processing to Address Challenges to Implementing High Strength Al Sheet
Principal Investigator: Efe Mert & Govindarajan Muralidharan, Pacific Northwest National Laboratory/Oak Ridge National Laboratory

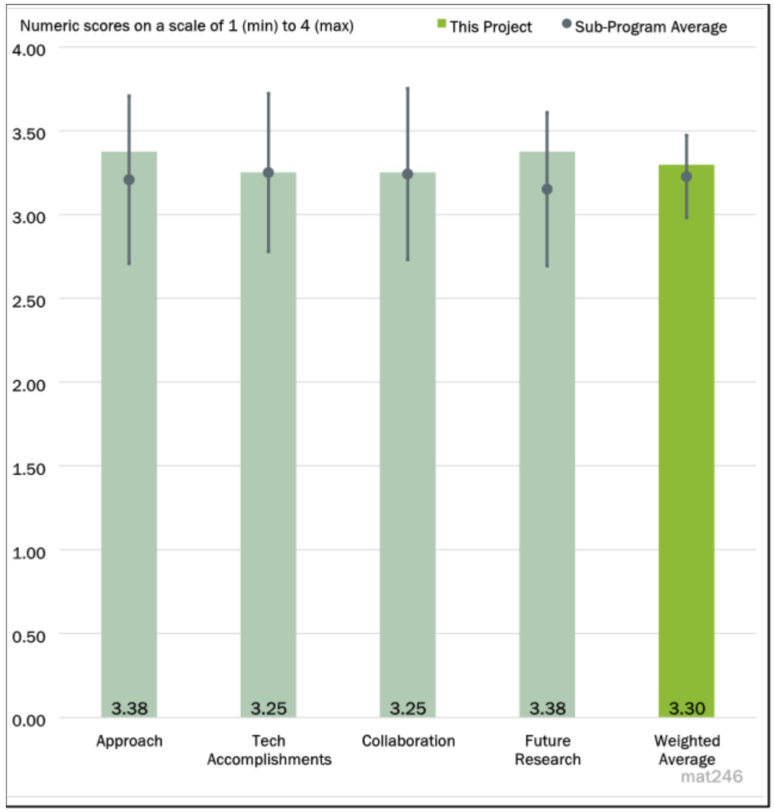

Figure 5-46 - Presentation Number: mat246 Presentation Title: LMCP P1C - Local Thermomechanical Processing to Address Challenges to Implementing High Strength Al Sheet Principal Investigator: Efe Mert & Govindarajan Muralidharan, Pacific Northwest National Laboratory/Oak Ridge National Laboratory

Presenter

Efe Mert and Govindarajan Muralidharan, PNNL/ORNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer noted that the program explores three distinct approaches to increasing formability of Al sheet locally. Good progress has been demonstrated. Over the past year, the focus has been on a specific component, which, along with initial work exploring cost, will be helpful in the goal of developing processes that can be adopted in industry. Going forward, closer work with industry partners is desirable. Further, since the project is part of a larger portfolio that involves advanced characterization and simulation, the reviewer suggests that the PIs should be encouraged to ensure that these tools are being exploited to advance progress. The reviewer found it difficult to tell from the presentation whether this is already occurring to significant extent.

Reviewer 2

This reviewer said that the technical considerations as well as the approach on an experimental level are on a high level. However, additional clarifying the exact field of application would be useful. The reviewer asked how far the proposed route of local microstructural alteration is being implemented in an industrial process and what the implications on process times and surface quality are.

Reviewer 3

This reviewer noted that the project proposed to evaluate three different routes to introduce localized surface/bulk microstructure/strain modifications to improve the formability of Al sheets. All three methods were rigorously selected and applied. The sheets were characterized using standard test methods and the performance was modeled. The reviewer suggested that long term performance such as fatigue, corrosion could be evaluated for completeness.

Reviewer 4

This reviewer noted that the project targets local thermomechanical processing to deliver local formability and can be delivered by the current plan.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer said that the team has achieved important progress in the overarching goal of local property modification (namely formability) in Al sheet using three different processes that it has demonstrated can be integrated with robots. Initial progress has been made on the assessment of feasibility and potential applications.

Reviewer 2

This reviewer noted that, while the effect on bendability is reported, the information on the development of strength is not complete.

Reviewer 3

This reviewer believes that, thus far, results suggest friction stir and laser processing will deliver local formability with potential industrial application but that it is not yet clear how roller processing would be industrialized.

Reviewer 4

This reviewer said that the performance of the sheet after the surface/bulk modifications was evaluated in all test conditions. Results indicate improved benefits of the processes. However, localized strains may impact the overall performance in long term use, suggesting a need for corrosion and fatigue testing.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer said that, within the team, there is sharing of materials and development of common test methods across the two participating labs. The right kind of industry collaborations are mentioned, but it was hard to assess whether more could or should be done in this regard. Finally, the reviewer said that collaborations with Thrust 4 in the LMCP portfolio were mentioned but the impact of these collaborations was not clear from the presentation, nor was whether closer collaborations could accelerate progress and understanding.

Reviewer 2

This reviewer said that there appears to be good collaboration amongst the project team.

Reviewer 3

This reviewer said that the project team is demonstrating collaboration among the lab partners and maintaining dialogue with the industry.

Reviewer 4

This reviewer found that, as of now the project is a collaboration between DOE labs; participation from OEM and from tier 1 and 2 suppliers could improve the reliability and usefulness.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The proposed future research seems well designed to address remaining barriers underlying the project goals. The connections to industry are encouraged to assess process feasibility and potential for applications.

Reviewer 2

This reviewer fully agrees with the proposed next steps.

Reviewer 3

This reviewer said that future investigations will include alloys of interest and will explore the influence of local thermomechanical processing on global formability.

Reviewer 4

This reviewer suggested that it should be useful to include long term exposure tests and fatigue.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the project is well aligned with the Lightweight Materials Program goals.

Reviewer 2

This reviewer said that the project bears relevance.

Reviewer 3

This reviewer said that this project is relevant to application of lightweight materials.

Reviewer 4

This reviewer said that more use of Al sheets can make light-weighting possible; improving the formability will reduce the cost of material substitution.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the resources available to each partner lab appear adequate based on the progress realized to date.

Reviewer 2

This reviewer said that there do not seem to be any shortages in resources.

Reviewer 3

This reviewer said that the resources are sufficient.

Reviewer 4

This reviewer said that, if additional testing for long term performance is added, then additional resources may be necessary

Presentation Number: mat247
Presentation Title: LMCP P2A - Solid Phase Processing of Aluminum Castings
Principal Investigator: Jana Saumyadeep & Zhili Feng, Pacific Northwest National Laboratory/Oak Ridge National Laboratory

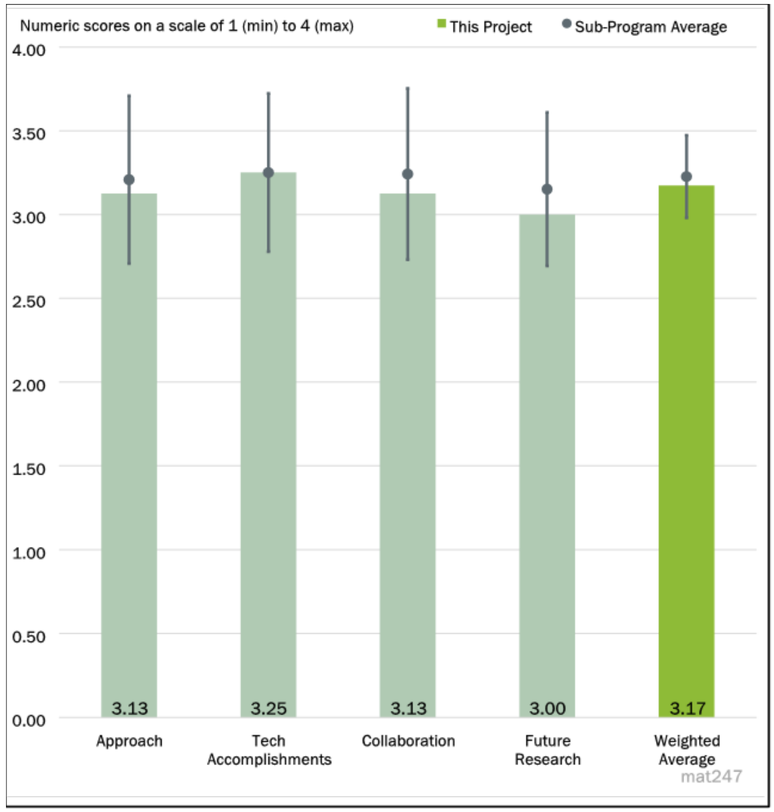

Figure 5-47 - Presentation Number: mat247 Presentation Title: LMCP P2A - Solid Phase Processing of Aluminum Castings Principal Investigator: Jana Saumyadeep & Zhili Feng, Pacific Northwest National Laboratory/Oak Ridge National Laboratory

Presenter

Jana Saumyadeep and Zhili Feng, PNNL/ORNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer found that the results presented so far show great promise in terms of improving the material performance. In the future, focus should be placed on an adaptability of the process to real components and processes. This appears in parts to be included in the current project plan.

Reviewer 2

This reviewer said that the technical barriers are being evaluated using the right methods of material testing.

Reviewer 3

This reviewer said that the project involves surface modification of die casting to improve the quality and performance. According to the reviewer, the team has accepted that the surface is the best part of the high-pressure die casting (HPDC) component, so that modifying it may not be the best option. However, by using the techniques to close internal pores the performance can be enhanced.

Reviewer 4

According to this reviewer, thus far, the work is good. The reviewer, however, sees potential issues in modifying the FSP and power ultrasonic surface processing (PUSP) platforms to work on real demonstration parts with complex shapes, as opposed to simple sample shapes. The reviewer suspects that it will take great efforts to develop the robotic tools to work on complex shapes of real parts in the time of the project.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer says that progress seems to be proceeding according to plan.

Reviewer 2

This reviewer feels that the project plan has demonstrated the opportunity for these technologies.

Reviewer 3

This reviewer says that the team had shown that it is possible to improve performance of die cast coupons but that the economic advantage of the procedures needs to be validated.

Reviewer 4

This reviewer believes that the researchers are making consistent progress on their respective tasks related to FSP and PUSP, and have been successful in meeting their milestones thus far. The reviewer, however, would like to see more microstructural characterization to detail the mechanisms that are leading to enhanced mechanical properties.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer said that the project has demonstrated collaboration among the lab partners as well as being informed with industrial perspective.

Reviewer 2

This reviewer found that the project is really parallel projects studying two separate methods for processing Al castings. Given the nature of the proposed research being two parallel projects, the level of collaboration seems satisfactory.

Reviewer 3

This researcher found that the approach of contrasting two competing processes by the two project partners provides good overlap.

Reviewer 4

This reviewer believes that lab to lab collaboration is good but no external partners are involved in this project.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer believes that the future of the project is aligned with industry needs.

Reviewer 2

This reviewer agrees with the next steps proposed.

Reviewer 3

This reviewer said that automation of the process to make it easier is a good idea, possibly reducing the cost during manufacturing.

Reviewer 4

This reviewer suspects that the research team will need to go to great efforts to develop the modifications to their experimental setups for processing realistic part shapes. According to the reviewer, it should also be studying the "heat affected zone" in FSPs as well. While this is not friction stir welding, there are still significant microstructural changes around FSP regions, particularly in Al with its relatively low processing temperatures.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer found that the project is relevant to the Materials subprogram, particularly the Lightweight Materials Area 1: improving the properties and manufacturability of light metals. The project is developing processing techniques to increase the viability of Al, which is directly relevant to lightweight materials.

Reviewer 2

This reviewer points out that the relevance is backed by examples of current developments in the automotive industry.

Reviewer 3

This reviewer says that the project is aligned with VTO objectives for materials.

Reviewer 4

This reviewer finds that the goal is very highly stretch; die cast Al is already improving energy efficiency. Property improvements may not justify using thinner sections but the reliability of the components may improve by the surface treatment.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer believes that the resources are sufficient, though suggesting that it may be difficult to make significant progress in developing methods for processing realistic shapes in the proposed time period.

Reviewer 2

This reviewer says that the resources seem to be fine.

Reviewer 3

This reviewer says that sufficient resources are being applied.

Reviewer 4

The reviewer remarked adequate resources.

Presentation Number: mat248
Presentation Title: LMCP P2B - High Intensity Thermal Treatment
Principal Investigator: Aashish Rohatgi, Pacific Northwest National Laboratory

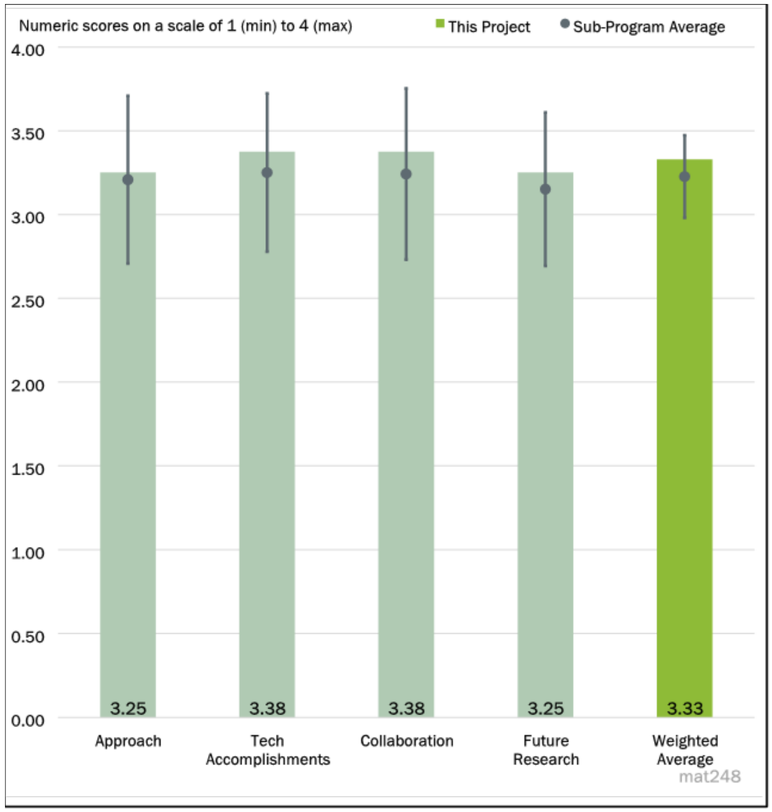

Figure 5-48 - Presentation Number: mat248 Presentation Title: LMCP P2B - High Intensity Thermal Treatment Principal Investigator: Aashish Rohatgi, Pacific Northwest National Laboratory

Presenter

Aashish Rohatgi, PNNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that the project consists of three distinct tasks, each addressing different strategies related to casting; heat treatment: and surface treatment. The overarching goal is to enable broader use of Al castings for light-weighting. The three tasks explore different routes to improving casting microstructures and enhancing local mechanical properties through cost-effective processes compatible with existing industrial casting approaches.

Reviewer 2

This reviewer said that the project has a reasonable plan and has been well designed.

Reviewer 3

According to this reviewer, the project is well designed. The reviewer found it encouraging that the researchers are considering the variation in properties as a function of distance from the treated region in their plans, which is important for real parts.

Reviewer 4

This reviewer believed that the work accomplished so far greatly shows the feasibility and microstructural effect of this new processing technique. Further work should include a more detailed characterization of the benefits, especially property improvements, at a broader scale. The hypothesis of higher effectiveness for secondary alloys should find some deeper focus, as this has the potential to greatly expand the field of application of recycled alloy material.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer believed that most of the accomplishments described were related to Task 1 and involve demonstration of impressive progress in the use of ultrasound to achieve microstructural refinement in cast alloys, as well as refinement of brittle Fe-containing phases that could enable greater use of recycled materials. Progress under this task includes collaborative work with the modeling thrust and in-situ characterization, which will greatly advance understanding of the origin of the effects of ultrasound.

Reviewer 2

This reviewer said that the work seems to be on track.

Reviewer 3

This reviewer said that progress made is aligned with the project plan.

Reviewer 4

This reviewer said that the results so far are impressive and they have shown a significant change in the microstructure due to ultrasonic processing during casting.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer noted that the project features strong collaborations with ORNL and ANL on solidification modeling and in-situ characterization at the Advanced Photon Source (APS), as well as PNNL for modeling and ultrasonics and microstructure analysis. The collaborations with Eck Industries are viewed as important for maximizing the potential for adoption of the processes investigated in this project.

Reviewer 2

This reviewer believed that the researchers are collaborating via discussions with an industrial partner, and experiments with other national labs. The proposed work with ORNL on applying their method to A356, and the in-situ diffraction experiments that were successfully proposed with APS will be enlightening for the project and for future work in this area.

Reviewer 3

This reviewer said that the project is well informed by industry perspective.

Reviewer 4

This reviewer said that the collaboration seems to work well.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that understanding the mechanism of microstructural refinement is particularly important for this research, and the proposed in-situ diffraction experiments at APS should help understand these mechanisms. The reviewer believed that it will be beneficial if the researchers can demonstrate microstructural refinement with a realistic demonstration part.

Reviewer 2

This reviewer said that the future research plan is rightly targeting opportunities in high pressure die casting.

Reviewer 3

This reviewer found the proposed work in Task 1 to be well designed to address the remaining barriers. For Task 2, not enough detail was given for this reviewer to judge the likelihood of achieving targets. Task 3 is to be commenced, but given that the project is half way over, and the remaining work to be done under the other two tasks, this reviewer wonders if a refocusing would be worthwhile that de-emphasizes Task 3.

Reviewer 4

This reviewer favors having the team focus on a full characterization of the mechanical property spectrum.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer found that the project is well aligned with the LMCP goals and appears unique within this portfolio in its focus on cast alloys.

Reviewer 2

This reviewer said that the project is particularly relevant to the lightweight materials portfolio of the Materials Technology Subprogram of the Materials Program objectives. It has shown success so far on research samples, and if successfully applied to realistic parts, will increase the recyclability, and thus cost, of Al for castings.

Reviewer 3

This reviewer believed that the aspect of secondary alloys shows great promise.

Reviewer 4

This reviewer said that the project supports the overall VTO subprogram objectives in lightweight materials.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the progress demonstrated suggests that resources for Task 1 are adequate. The reviewer asked whether, given the challenges described with the HPDC sample, other sources of material will be required to enable progress in Task 2. The reviewer was unable to judge the resources for Task 3.

Reviewer 2

This reviewer said that the resources seem to be sufficient and the researchers are leveraging collaborations with other labs effectively.

Reviewer 3

This reviewer said that the resources seem sufficient.

Reviewer 4

This reviewer said that the project resources are sufficient for the plan.

Presentation Number: mat249
Presentation Title: LMCP P2C - Cast-and-Print - AM for Localized Property Enhancement of Al castings
Principal Investigator: Alex Plotkowski, Oak Ridge National Laboratory

Presenter

Alex Plotkowski, ORNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

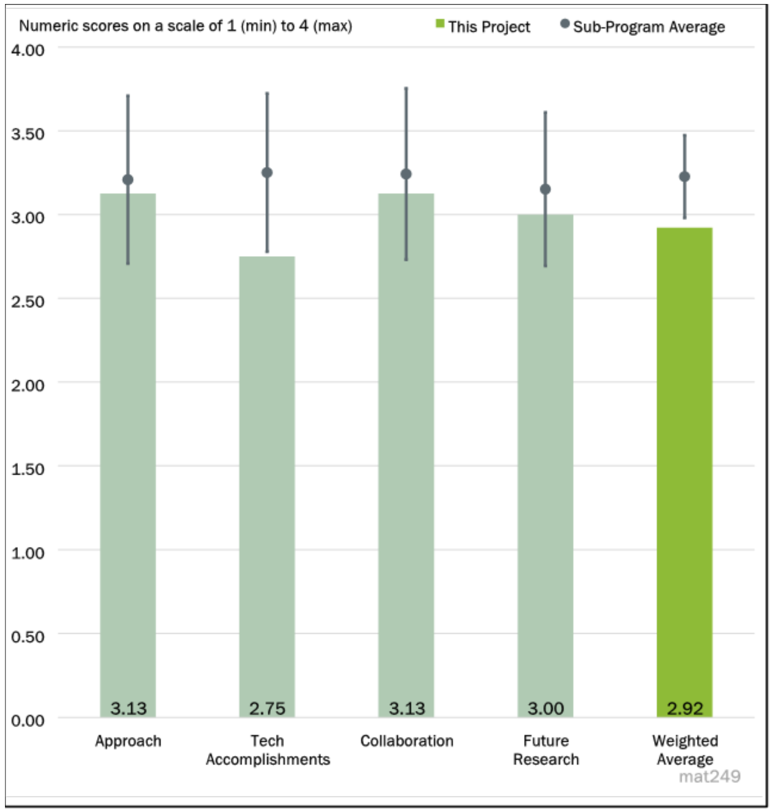

Figure 5-49 - Presentation Number: mat249 Presentation Title: LMCP P2C - Cast-and-Print - AM for Localized Property Enhancement of Al castings Principal Investigator: Alex Plotkowski, Oak Ridge National Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

This reviewer found that the approach taken to execute work is good. The technical barriers seem to be addressed in a way that would result in meeting the stated goals of the project.

Reviewer 2

This reviewer said that the PI identified a good approach for determining the effect of printing on cast surfaces. The reviewer did not find it clear what drives the choice of 4X and 5X alloys as the printed material on 356 castings and asked if there is a specific part or assembly that is driving this research.

Reviewer 3

This reviewer said that the research team successfully identified technical barriers that arose while evaluating their printing process by adding a machining step between each step. It is effectively leveraging a parallel project in computation to study and potentially improve their procedure by optimizing gas flow during the process. It is, however, unclear how a change in the part's geometry will change the gas flow locally, so this may be something the team needs to consider as well when it has determined the demonstration part's geometry.

Reviewer 4

This reviewer expressed difficulties understanding the scope of this project, having missed the presentation due to illness. The reviewer asked what the benefits of introducing an additional, slow AD-manufacturing step are, as opposed to proper alloy selection or a multi-component design. and whether a cost benefit can be expected. The reviewer said that the benefits in terms of mechanical properties are not clearly presented.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer believed that, at this stage of the work (50% complete), the progress in addressing the technical barriers is good. Some issues, like the oxide film that deposits on the surface of each pass, have been identified and are being dealt with. Other issues like the shrinkages and material strains that are experienced in the solidified material have also been identified as needing a solution/attention.

Reviewer 2

The reviewer said it would be great to see the effects of process conditions on the different sample performance, especially in terms of mechanical properties at the cast/print interface. The reviewer questioned how the performance of the cast/print parts would compare with other joining methods, such as welded 356/4043 or 356/5356 joints and asked what the alternate plans are if the deposition gas issue is not resolved.

Reviewer 3

This reviewer said that the quality of AM does not seem to be great in showing sufficient dimensional accuracy.

Reviewer 4

This reviewer stated that the results shown in the presentation demonstrate that progress has been made. The team has been able to identify issues with the formation of oxide during the process and alter the procedure accordingly. It was able to print a “simple” geometry part using the print and machine procedure. The reviewer would like to know how the machining step will alter the time requirements for their method.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer found excellent coordination between the different thrusts of the LMCP project.

Reviewer 2

This reviewer found that the collaboration with the parallel LMCP Thrust 4 is good, and, hopefully, can be a substantial addition to understanding the process, especially as printed parts’ geometries and sizes are altered. The reviewer felt that it would be good to demonstrate more collaboration with the industrial partners; hopefully, this will occur naturally as the later tasks are being completed. Choosing a representative part should necessitate significant communication with the industrial and research partners.

Reviewer 3

This reviewer said that the partners appear to be well coordinated. There appear to be good and effective synergies.

Reviewer 4

This reviewer said that there appears to be good collaboration amongst the project partners, including contact with industry.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer found it encouraging to see demonstration of automotive relevant geometries as a future plan.

Reviewer 2

This reviewer believed that a good path forward has been laid out. It will address a majority of the technical barriers that still remain, including the quantification of strain, shrinkage in the build and how to mitigate them. The reviewer noted that a cost analysis for the end product(s) will also be needed.

Reviewer 3

This reviewer felt that the benefits of the approach need to be clarified.

Reviewer 4

This reviewer said that the researchers have been successful in identifying and addressing issues with the printing procedure by adding a machining step. The team is working with DOE collaborators as well for computational modeling of parts of the process, which should provide good feedback for the process in the future. The reviewer believed that it would be useful to see more collaboration with their industrial partners.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the project is relevant to the Materials Technology Subprogram, addressing directly lightweight materials, as it can directly lead to improved manufacturability of Al metals with superior properties. The reviewer also said that the results can provide relevant and required data to collaborators working on ICME tools for modeling the manufacturing process, and for modeling the microstructure in AM parts for virtual testing.

Reviewer 2

This reviewer said that the deposition process contributes to materials engineering advancement. It also contributes to light-weighting, which improves fuel efficiency in vehicles.

Reviewer 3

This reviewer believed that developing cast/print process for complex automotive part geometries is relevant research for the VTO portfolio.

Reviewer 4

This reviewer was uncertain of the relevance, finding, the benefits to be unclear at this stage.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the resources are sufficient. The team is also leveraging the results of collaborators from another thrust, which may provide a better return on the research investment.

Reviewer 2

This reviewer said that there is no indication at this point that the available funds will not be adequate to complete the targeted scope

Reviewer 3

This reviewer said that sufficient resources are available for the completion of upcoming tasks.

Reviewer 4

This reviewer noted that no insufficiencies were reported.

Presentation Number: mat250
Presentation Title: LMCP P3A - Cast Magnesium Local Corrosion Mitigation
Principal Investigator: Joshi Vineet & Jiheon Jun, Pacific Northwest National Laboratory/Oak Ridge National Laboratory

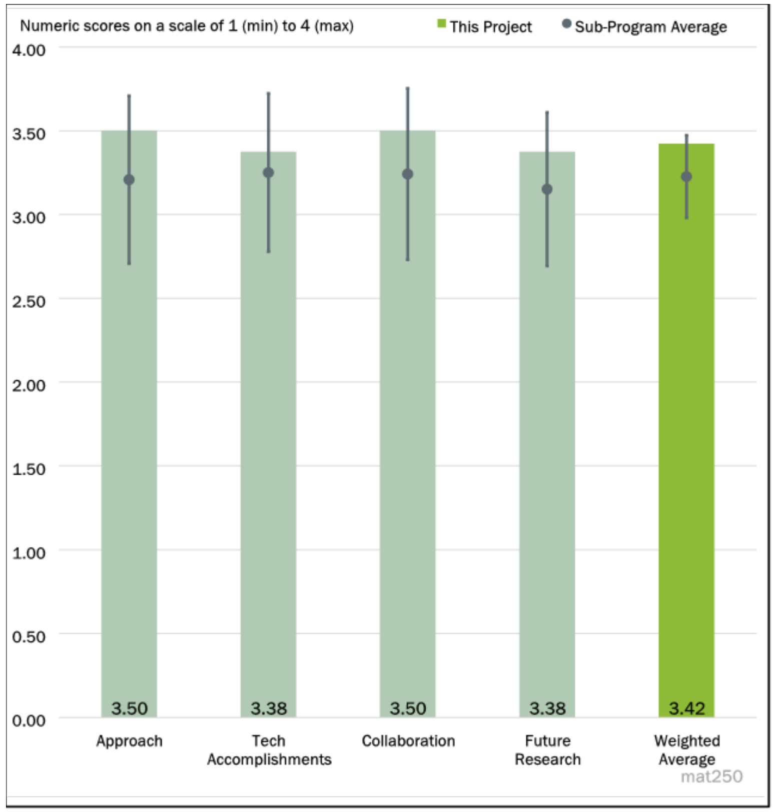

Figure 5-50 - Presentation Number: mat250 Presentation Title: LMCP P3A - Cast Magnesium Local Corrosion Mitigation Principal Investigator: Joshi Vineet & Jiheon Jun, Pacific Northwest National Laboratory/Oak Ridge National Laboratory

Presenter

Joshi Vineet and Jiheon Jun, PNNL/ORNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that Mg cast parts offer excellent opportunities for vehicle light-weighting, reduced part and alloy count, and lowered assembly costs, but cast Mg is prone to corrosion. This project seeks a novel cost effective surface coating method to improve the cast Mg part's corrosion properties. Two approaches were used: reactive surface treatment (ORNL) and surface alloying (PPNL). Both have solid scientific foundation. The original 3 years' plan was reasonable. It seems that the team has overcome the COVIDCOVID-19 situation and managed to keep the project schedule on time.

Reviewer 2

This reviewer noted that the parallel 3A2 projects have well defined milestones, which the researchers are meeting. The team has shown an improvement in corrosion resistance using each surface treatment technique.

Reviewer 3

This reviewer stated that the testing approaches of Thrust 3 are comprehensive to evaluate the corrosion and mechanical behavior.

Reviewer 4

This reviewer believed that the project is directly addressing the technical barriers. However, the reviewer suggested that it would be very helpful for all involved if the project clearly communicated the team's assessment of the technology readiness level the technology is at and where the team expects to be at the end of the project.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer said the team made good progress. The plasma surface treatment achieved 2.4X corrosion reaction resistance for AZ91D alloy; the lithium-salt and thermal CO_2 treatment even demonstrated 10X improvement for AZ91D. The cold-spray of Al on Mg substrate improved corrosion resistance by 6X; reactive Zn coating improved corrosion resistance by 3X. These examples of progress are impressive.

Reviewer 2

This reviewer pointed out that, on the slide of "Milestones" only checks are marked on the status. The reviewer found it unclear whether this refers to a 100% completion or that it has been initiated.

Reviewer 3

This reviewer said that the researchers have successfully improved the corrosion properties in both project 3A1 and 3A2. The team has also shown better wear properties in samples from the cold spray technique of 3A2. The reviewer would find it interesting for the researchers to study in more detail the area of severe plastic deformation between the AZ91 and commercially pure Al coating on the samples from 3A2 to verify the phase and level of damage in the region.

Reviewer 4

This reviewer stated that, overall the work is interesting and making progress, though, in general, it seems that this project is attempting to cover a lot of ground. The reviewer believes that knowing what TRL the project is at and what it is trying to achieve will assist in setting expectations. According to the timetable for A1, "optimal" process parameters have been developed, though on Slide 8 there are only 2 Nyquist plots. So, it is difficult to make an assessment that optimal parameters have been developed or what is the fundamental mechanism behind what determines the optimal process parameters. Regarding A2, Slide 11 it is not clear why the data was collected at such higher pressures and temperatures since the reviewer believes that the project is not to develop a new cold spray system. The reviewer asks whether the equipment performance is relatively new compared to the published literature, suggesting that a bit more elaboration is warranted.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer was gratified to see ORNL and PNNL working so closely. However, Industry's contribution is yet be shown. I guess once the project is a bit more mature, industry will be more engaged?

Reviewer 2

This reviewer found the collaborations between national labs, university and companies to be well addressed and integrated for this Thrust 3.

Reviewer 3

This reviewer noted that there is collaboration between ORNL and PNNL researchers for their parallel coating processes. 3A is also supported by computation studies from Thrust 4. It would be good in future to discuss some of the input, feedback, or insight the team has obtained from the computational results. The microstructural characterization is being performed by Project 3B. The team has also received materials and cast parts from an industry partner. There appears to be a very good level of collaboration between the groups working on or providing materials and results for this work.

Reviewer 4

This reviewer found that there is clear collaboration across projects with materials and analysis in addition to external industry collaborators.

*Question 4: **Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?***

Reviewer 1

This reviewer believed that the proposed work, long term corrosion tests, multimodal corrosion test, and coating on actual parts are spot-on.

Reviewer 2

This reviewer said that the proposed future work meets the research goal and addresses the research challenges.

Reviewer 3

This reviewer said that the proposed future work is good. The team is aware of the challenges with scale-up and is applying its methods on real parts, and working towards those goals.

Reviewer 4

This reviewer believed that the project would benefit from incorporation of baseline industrial solutions to help understand if there is a performance and/or cost benefit to the technologies investigated in this project. Otherwise, the reviewer said that the future work is a logical extension of the work to date.

*Question 5: **Relevance: Does the project support the overall VTO subprogram objectives?***

Reviewer 1

This reviewer found that the project is clearly relevant to the Materials Technology Subprogram, and aims to improve the corrosion and wear properties of Mg. It is directly supporting the VTO subprogram objectives.

Reviewer 2

This reviewer found the work relevant because the application of Mg provides significant mass savings opportunities which is in-line with the DOE roadmap of greenhouse gas emission reductions via mass savings. And since the single most significant technical roadblock to implementing Mg is corrosion performance, this project can clearly be seen to support the DOE objectives.

Reviewer 3

This reviewer said that the project aims at enhancing corrosion resistance and improving the wear resistance of cast Mg to address shortcomings of typical commercial Mg alloy castings.

Reviewer 4

This reviewer noted that joining of dissimilar materials is an important area in advanced manufacturing for DOE to reduce the structural weight and improve component performance and energy efficiency. Corrosion is a critical barrier in broadening the application of dissimilar materials joints. This research aims to address this issue by modifying the bonding surfaces to improve the galvanic corrosion resistance.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the resources are sufficient, and the researchers are also able to leverage the results and work of two other projects, one from Task 3 and one from Thrust 4.

Reviewer 2

This reviewer said that the resources appear to be sufficient, given that the last year is focused on long-term corrosion testing, which requires less HC to manage, albeit over a greater duration than the first half of the project. However, a deeper dive into some of the fundamental questions around what constitutes an optimum oxide layer and why would certainly require significantly more resources.

Reviewer 3

This reviewer said that the resource for the project is appropriate.

Reviewer 4

This reviewer said that the team has enough resources to fulfill the research goals on time.

Presentation Number: mat251
Presentation Title: LMCP P3B - Thermomechanical Property Modification of Mg Castings
Principal Investigator: Mageshwari Komarasamy, Pacific Northwest National Laboratory

Presenter

Mageshwari Komarasamy, PNNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

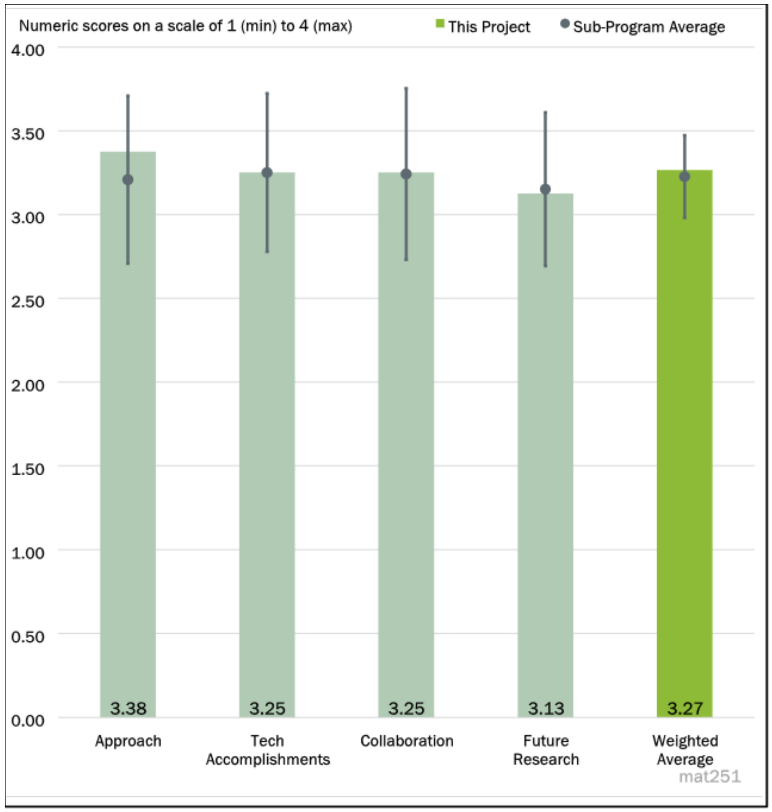

Figure 5-51 - Presentation Number: mat251 Presentation Title: LMCP P3B - Thermomechanical Property Modification of Mg Castings Principal Investigator: Mageshwari Komarasamy, Pacific Northwest National Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The project design addresses critical barriers to local property enhancement, namely the complexity of the geometry of automotive components. The timeline appears fairly sufficient with 3 months of spacing between milestones, although investigation into curved geometry would require more rigorous testing and should be conducted on multiple types of geometries, so perhaps more time could have been allotted. Task 3 in FY23 will address component-level processing and local alloying for 3-D components.

Reviewer 2

This reviewer found that the project clearly addressed the barriers and exceeded most targets. Strength was increased by up to 40% and the improvement in fatigue life was better than targeted (20X achieved vs. 5X targeted) for alloy AZ91. The improvement in properties was the result of friction stir processing, reducing porosity of AZ91 from 1.6% to 0.0003%. The elongation percent of AZ91 increased from 4% as-cast to 18% with a double pass, but decreased back to near 4% after double pass and various T5 heat treatments. It wasn't clear to the reviewer how the combination of FSP single or double pass and subsequent heat treatment(s) relate to the final practical goals for an AZ91 casting. It also was not clear what condition of AZ91 FSP specimen from Slide 8 was fatigue tested in Slide 9 to offer these remarkable lifetime increases but the reviewer believed that it was one of the higher ductility conditions. The reviewer believed that it would be even better to have seen fatigue life as a function of the various processing and heat treatment conditions, particularly since ductility was quite variable after heat treatment.

The AM60 alloy seemed to show clear improvements in ductility after FSP, but yield strength decreased vs the as-cast condition, although ultimate tensile strength increased. The AM60 also showed a 10X improvement in fatigue life, but again it wasn't clear under which FSP condition(s). Porosity was again drastically reduced (1.6% to 0.01%) after FSP, which enabled the improvements in ductility and fatigue life.

Reviewer 3

This reviewer found that the project is improving the local properties of Mg alloys (AZ91 and AM60) by reducing the porosity level via the friction stirring process and found that the approach is well-designed and appropriate.

Reviewer 4

This reviewer believed that the technical barriers have been, thus far, addressed. However, the change to the FSP setup for processing real parts and curved plates with curvature greater than 15 degrees will likely take significant development. The team is aware of this, but it would be useful to see how it plans to address these issues.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

This reviewer pointed out that the first milestone is complete, and it addressed one of the primary challenges of the project. The significant increases in ductility and fatigue life demonstrate the efficacy of the FSP process. However, automotive components will involve complex geometries that were not addressed by the first milestone. While the team successfully demonstrated FSP on curved surfaces as planned, they had not completed mechanical property investigation of the curved FSP material at the time of the AMR, and this milestone was set to be completed by 6/30. The milestone was listed as on-track, so it was possibly completed on time.

The team was very effective at ascertaining the process parameters needed to avoid defects. The 53% increase in yield strength of AZ91 is impressive, as is the improvement in fatigue life. Overall, the mechanical benefits of FSP were well-demonstrated. It is promising that defects could be avoided with the 15 degree curved surfaces. However, the 45and 90 degree curves may pose more significant challenges.

Depending on the target components for local alloying, it may be relevant to study the temperature behavior of the treated components and conduct mechanical tests at varying temperatures. For instance, a brake component may get very hot, so the part should be able to maintain its integrity at high temperature.

Reviewer 2

This reviewer said that the results, thus far, are impressive, and the researchers were able to achieve an order of magnitude increase in fatigue life versus high pressure die cast material without skin. The researchers should consider the heat affected zone at the boundary of the FSP nugget in order to see if there was any deleterious effect on the microstructure there, and predict if it could have a negative side effect on mechanical or fatigue properties. FSW materials will sometimes fail at the boundary between the nugget and surrounding material.

Reviewer 3

According to this reviewer, the project has made excellent progress toward meeting most project goals. The project is now incorporating a commercial cast component via Meridian, which is an outstanding addition for evaluating commercial feasibility for this process. The ability to process curved plates further elevates the potential practical value of the FSP process.

According to the reviewer, there were a few issues that were not clearly addressed. First of these was the anticipated effects of the entry and exit points of the FSP tool. The plate shown in Slide 13 shows a clear discontinuity at the tool entry point on the right side. It would be of value for potential industry adopters to know how such features might impact the fatigue life of the material, and whether/how such effect would be mitigated (perhaps by post processing via one or more subsequent finishing steps). Second, the reviewer suggests that it would be very helpful to see simulations of the range of anticipated minimum tool loads normal to the processing surface relative to the stress/strain anticipated for a range of expected wall thicknesses and related component geometry of die cast Mg components. The reviewer asks whether the FSP process is anticipated to induce plastic deformation in the range of expected thin wall hollow AZ91 or AM60 die cast components. Such loading information would assist in defining the range of applicability of this intriguing processing method for thin-walled, hollow, lightweight cast components.

Reviewer 4

The reviewer said that the project has accomplished proposed milestones and making a good progress.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer noted that the national labs involved collaborated on corrosion testing and advanced characterization, and an industry partner (Meridian) provided coupons and components.

Reviewer 2

This reviewer found that relevant and valuable collaborations, at various stages of maturity were briefly described between PNNL, ANL, ORNL, and Meridian. These involve corrosion, advanced characterization, and provision of HPDC coupons and components.

Reviewer 3

This reviewer said that the researchers are collaborating with others at PNNL, ORNL, and ANL through Project 3A and Thrust 4, as well as with an industrial partner, which has provided high pressure die cast samples. The team reports having discussions with its industrial partner as well. Hopefully it is engaging in active dialogue with regard to this project and how to target certain regions in automotive castings.

Reviewer 4

This reviewer stated that, as of AMR 2022, only the collaboration between Meridian and PNNL is presented, and the contribution from other participants (ORNL and ANL) is barely introduced.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the proposed future research is clear, within scope, and achievable.

Reviewer 2

This reviewer said that the proposed future work has been clearly defined. The researchers are aware that there will be significant challenges in applying the FSP methods on real castings, and plan to work towards these goals, while also quantifying the effect of the process on properties.

Reviewer 3

This reviewer said that the description and intent to apply FSP to alloy local areas is interesting but any advantages relative to simpler and lower cost coating methods were not clear.

Reviewer 4

This reviewer said that the proposed future work tasks are reasonable and within the overall project scope.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that local strengthening of lightweight materials will enable their use in high strength applications.

Reviewer 2

This reviewer said that the project is clearly relevant to the Materials Technology Subprogram, and aims to improve the mechanical properties of Mg, having so far shown an increase in the fatigue and mechanical properties of samples through FSP. It is directly supporting the VTO subprogram objectives.

Reviewer 3

This reviewer said that the project clearly supports overall VTO subprogram objectives.

Reviewer 4

This reviewer said that the objective of the project is well-aligned with the overall VTO program.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer found that the resources are sufficient, considering the equipment, expertise, and personnel available.

Reviewer 2

This reviewer believed that, while the next steps in the project will be difficult to achieve, the researchers have sufficient resources, and appear to be collaborating effectively with the other Project 3 and Thrust 4 researchers.

Reviewer 3

This reviewer believed that resources appeared sufficient for the described research.

Reviewer 4

This reviewer said that the resources of the project are sufficient to perform all the proposed tasks.

Presentation Number: mat252
Presentation Title: LMCP - Thrust 4 - Materials Lifecycle
Principal Investigator: Jeff Spangenberger, Argonne National Laboratory

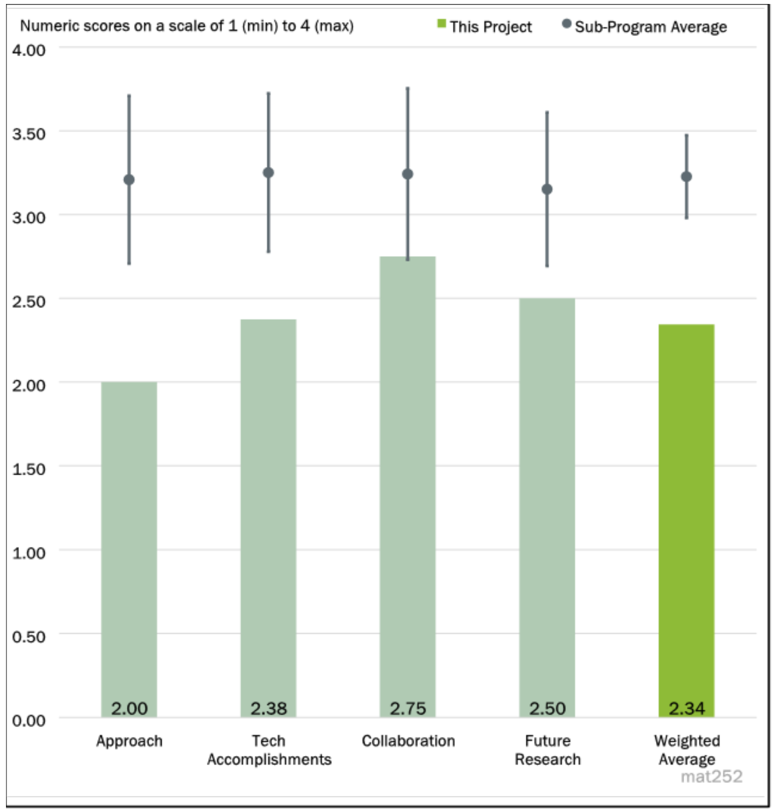

Figure 5-52 - Presentation Number: mat252 Presentation Title: LMCP - Thrust 4 - Materials Lifecycle Principal Investigator: Jeff Spangenberger, Argonne National Laboratory

Presenter

Jeff Spangenberger, ANL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

This reviewer found the goals and objectives of the project to be somewhat vague and suggested that the team should consider how it would know if/when it had been successful in terms of tangible outcomes. is the reviewer also found it unclear if the overall objective of the project is to reduce the use of alloys or, generally, to ensure that light-weighting efforts do not negatively impact recyclability. The reviewer believed that, if it is the latter, then there may be other solutions besides reducing use of alloys, such as reducing use of adhesives or tertiary materials.

The reviewer noted that, although a timeline is presented, the milestones lack specificity. The most notable technical barrier addressed is understanding the needs and capabilities of end-of-life industry stakeholders. More clearly enumerated/quantified technical barriers would be helpful.

Reviewer 2

This reviewer said that the project would benefit from identifying specific materials whose lifecycle infrastructure can be examined in a scoping study rather than performing them for ‘all materials’ in a vehicle. As an example, the reviewer favored looking at the Al alloys being used predominantly amongst the LMCP projects and aligning s the scoping study accordingly.

The reviewer also believed that it would be preferable to identify who the various stakeholders are relating to non-ferrous materials who will be interviewed to understand the recyclability, separations, and material lifecycle considerations.

Reviewer 3

This reviewer believed that the approach seems to be limited to scoping in the evaluation period. The reviewer suggested that, while the project size is small, some recommendations for life cycle analysis will benefit other PIs and the larger community.

Reviewer 4

This reviewer said that the presentation provided zero examples of specific conversations, specific technical examples, specific activities, or specific technical recommendations related to any of the multiple tasks within the program. All information provided was remarkably generic or commonly available information.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer said that, as this is a scoping study, the technical accomplishments are mostly related to understanding the potential for increasing recyclability across the Materials Program. The team uncovered opportunity areas through conversations with other researchers. That is sufficient for the purposes of this study. However, some quantification of the opportunity would make the technical accomplishments clearer, such as the percentage of light materials projects that can contribute to reduction in the number of alloys, at various scales. These values, even if only preliminary, would clarify the impact of this work.

Reviewer 2

This reviewer said that the project presents the premise of the LMCP as a key finding and that this messaging may have to be modified. The reviewer expressed a need to understand what alloys/materials were discussed as part of the conversations with the industry stakeholders.

Reviewer 3

This reviewer noted that it is difficult to evaluate progress when the metrics and milestones are so qualitative. Visiting companies, having conversations, etc. are difficult to assign a score to.

Reviewer 4

This reviewer said that there were no examples of progress or specific contributions, other than conversations with industry (nothing specific described) as a milestone and a visit to a heavy media recycling plant as a quarter 3 milestone. But, the reviewer said, the examples of technical accomplishments, particularly as a Year 2 effort, did not provide unique contributions. For example, under Technical Accomplishments and Progress the following were provided: 1) “Aluminum recycling enjoys a huge energy and GHG benefit compared to steel;” 2) “We need to ensure that recyclability doesn’t get sacrificed, instead improve recyclability;” 3) “The main findings during meetings and interaction with the teams demonstrated that it is possible to increase the amount of lightweight metals in vehicles while reducing the number of alloys.” The reviewer pointed out that these are statements of well-known facts, known from the launch of the program, are not actual accomplishments, and they provide no clear picture of Year 2 activities or progress.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer pointed out that collaboration is the name of the game for this project. The team worked extensively with other research teams and industry stakeholders to understand the problems and opportunities.

Reviewer 2

This reviewer was gratified to see this project interacting with the various teams and the industry stakeholders but asked how often collaboration meetings occur, saying that this is not clear from the presentation.

Reviewer 3

This reviewer said that there were conversations described with some of the program tasks, but no details of which tasks or what specific details were discussed or what recommendations were made to impact the tasks. The most specific detail offered was "Local treatments change performance as needed to reduce multiple alloys."

Reviewer 4

It was not clear to the reviewer how other LMCP projects are benefitting from this effort.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that most of the proposed future work is a logical continuation of the work that has already begun. However, development of a lifecycle cost and environmental impact tool seems to widen the scope or be somewhat tangential. The team will need to carefully manage their goals to stay on track.

Reviewer 2

This reviewer said that a tool to identify the changes in material lifecycle corresponding to process changes, especially in the context of the LMCP, is a great approach for future work.

Reviewer 3

This reviewer said that the metrics and milestones need to be SMART for this project.

Reviewer 4

This reviewer noted that the proposed future work stated that it would continue current efforts with program thrust groups and industry, as well as visit the heavy media plant. These were all generically included in the current presentation; thus, their continuation offers no clearly defined purpose. The reviewer agreed with the team that a lifecycle cost and environmental impact tool should be developed, but found that the development of such a tool is not clearly proposed beyond stating- the need for it.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the project is relevant because it supports increased sustainability of materials.

Reviewer 2

This reviewer stated that the concept of the project is definitely relevant and important but the execution of the project needs substantial clarification and improvement in order to deliver relevant outcomes in Year 3.

Reviewer 3

This reviewer said that the project is very relevant to the LMCP and VTO portfolio.

Reviewer 4

This reviewer said that the project is relevant for LMCP.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the team appears sufficient as-is. However, if a lifecycle cost and environmental impact tool will be pursued, then additional expertise may need to be brought in.

Reviewer 2

This reviewer opined that the resources appear more than sufficient for the outcomes described. This could be a very impactful task to the Light Metals Core Program with appropriate planning and effort.

Reviewer 3

This reviewer said that sufficient resources are available for the upcoming tasks.

Reviewer 4

This reviewer said that the resources are sufficient for the progress made.

Presentation Number: mat253
Presentation Title: Flexible, Lightweight Nanocomposites for EMI Shielding Suppression in Automotive Applications
Principal Investigator: Carla Lake, Applied Sciences

Presenter

Carla Lake, Applied Sciences

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

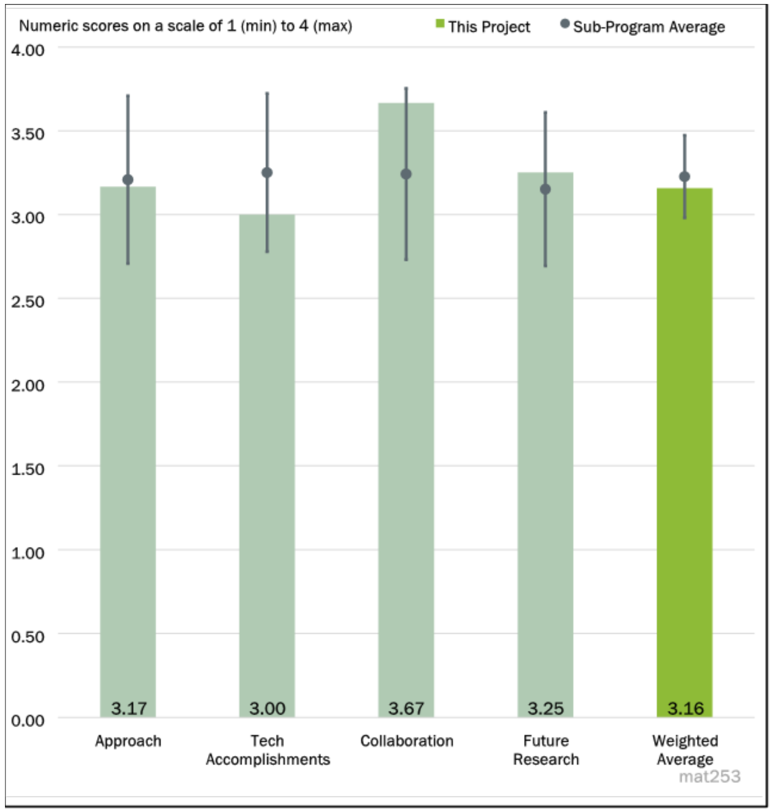

Figure 5-53 - Presentation Number: mat253 Presentation Title: Flexible, Lightweight Nanocomposites for EMI Shielding Suppression in Automotive Applications Principal Investigator: Carla Lake, Applied Sciences

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

This reviewer said that the project team clearly laid out its work, how it approaches its experimental design, and the motivation for certain vehicle components to have and need shielding. The team also showed a lot of results in bullet points; however, where performance was improved over the state of the art materials, more data should be provided. The selected production method is both low cost and scalable, aligning with VTO goals

Reviewer 2

This reviewer noted that this was a small one year project and has now been completed. The project focused on validation and structure/performance tailoring for the industrial performer’s lightweight electromagnetic interference (EMI) shielding material. The composite product developed here would replace heavier metal braid harnesses. This project is compelling, as it focuses on a light-weighting application area that has been relatively little pursued.

Reviewer 3

This reviewer noted that the intent of the project is to develop nanocomposites for EMI shielding. The approach is good, but it is not perfectly clear if commercially competitive high performance EMI shielding materials can be achieved.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer found that the project made good progress over the one year timeframe, especially given the limited project size and budget.

Reviewer 2

This reviewer said that the team laid out its approach to the work clearly and mentions a wide variety of successes. The main goal of EMI shielding at a respectable scale has been achieved. It would have been great to see more data supporting the claims of enhanced performance over the incumbent materials, which could lead to faster adoption.

Reviewer 3

This reviewer said that it appears that the team has demonstrated 99% shielding efficiency. Since the detail is not visible, it is hard to tell what kind of samples achieved sufficient performance, which depends on material thickness, composition, etc. If commercially viable performance and materials' costs had been clearly defined, the performance could be evaluated in a fair fashion but that information was not available.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer stated that collaborations/partnerships were very valuable in this project considering the small size of the business involved. The partnerships developed here may result in commercialization of this lightweight product.

Reviewer 2

This reviewer said that the team clearly laid out all of its collaborators and their roles.

Reviewer 3

This reviewer said that the team has partners relevant to the vehicle applications.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer held that the project had accomplished the target and will end soon. Such future plan is appropriate.

Reviewer 2

This reviewer commented that it is not clear how much of the glider these materials could be used for and how much light-weighting they would impart making the value of the future research questionable. Recyclability is possibly one of the more exciting comments; however, these materials may not be suitable for recycling, especially if they contain PVC.

Reviewer 3

This reviewer noted that the project has ended but the future work suggestions, such as the recycling investigation, are good. An environmental life cycle assessment would also be helpful in understanding the overall potential benefit of a lightweight material in this application.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the project is well aligned with DOE objectives in light-weighting and composites.

Reviewer 2

This reviewer said that the work combines light-weighting with battery relevant considerations, delivering enhanced performance. Thus, the reviewer believed that it can be viewed to align with the sub program objectives.

Reviewer 3

This reviewer said that the technology is relevant to VTO.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the resources were sufficient.

Reviewer 2

This reviewer found that the team has made good progress with their budget.

Reviewer 3

This reviewer said that the team has completed most of the milestones and the resource is sufficient.

Presentation Number: mat255
Presentation Title: Graphene-enriched Hierarchical Polymer Additives Derived from Natural Gas
Principal Investigator: George Skoptsov, H. Quest Vanguard, Inc.

Presenter

George Skoptsov, H. Quest Vanguard, Inc.

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

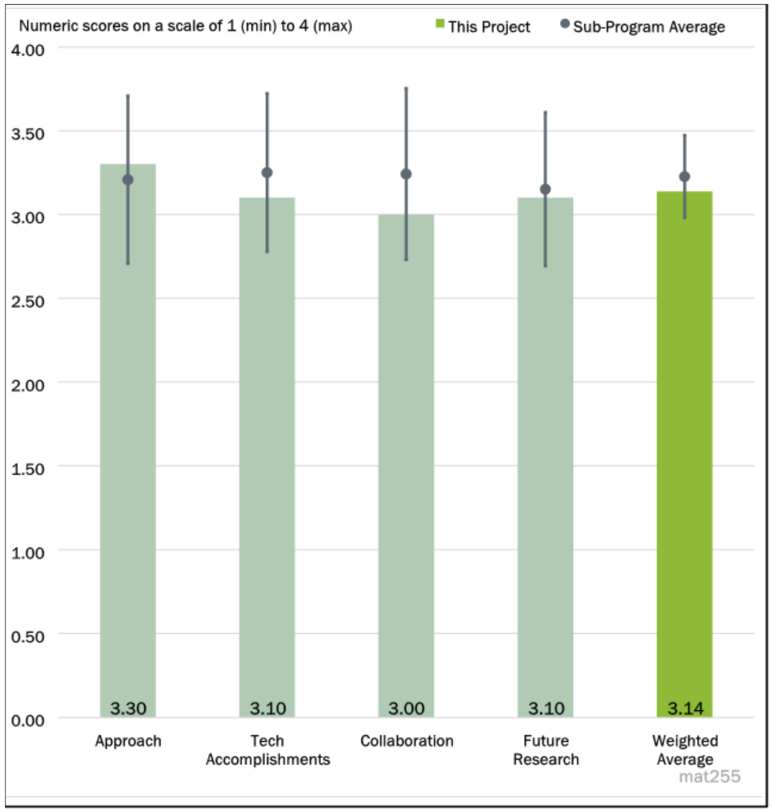

Figure 5-54 - Presentation Number: mat255 Presentation Title: Graphene-enriched Hierarchical Polymer Additives Derived from Natural Gas Principal Investigator: George Skoptsov, H. Quest Vanguard, Inc.

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

This reviewer believed that the project's approach is a great is great for increasing the tensile strength of injection-molded composite parts. Being that this is a rapid process to increase the carbon fiber surface area, the reviewer can see how this would enable adoption by the automotive industry.

Reviewer 2

This reviewer said that the approach does not directly contribute to the technical barriers described in the presentation for mass and weight reduction. These are usually achieved simply by using any type of carbon or composite fiber. The novel aspects of this approach is that it uses recycled carbon fiber, which could potentially reduce costs because an expensive precursor is not needed and uses a unique thermochemical process to rapidly treat carbon fiber and improve the tensile and shear strengths of the resulting thermoplastic composite material. The target of 70%-100% increase in ultimate tensile strength may be unrealistic, but any significant increase in strength for recycled carbon fiber would be an accomplishment. The project timeframe is less than a year, so the timeline to demonstrate the initial goal of an effective thermochemical process is reasonable.

Reviewer 3

This reviewer found that the project has identified and addressed the technical barriers. The microwave plasma approach was novel and well designed. The timeline is reasonable and achievable.

Reviewer 4

This reviewer said that the project layout and process tasking are adequately described at a high level. It would be useful to have a better description of targeted performance and what tests will be utilized to demonstrate progress towards those goals. It would be expected that dispersing carbon black into a composite would increase the Brunauer-Emmett-Teller [BET]-measured surface area regardless of how well-attached it is to the carbon fiber. Actual test data would inspire confidence in the reported observations.

Reviewer 5

This reviewer pointed out that the premise of the technology is that current grades of carbon fiber reinforced thermoplastic composites do not meet the performance requirements for automotive applications. Accordingly, it is proposed that improvements in interfacial strength are required to achieve a corresponding increase in composite strength. According to the reviewer, in practice, many automotive applications are limited by stiffness and not strength. Therefore, application of the microwave plasma ad graphene is likely to be cost prohibitive.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer found that all technical accomplishments have been met with very promising results and the project remains on schedule. The reviewer would like to see more on the mechanical property improvements; the preliminary results look great, so more testing would help convey the impact this research could have.

Reviewer 2

This reviewer said that the project is on track and has accomplished 80%. The milestones are achievable.

The project may do Raman spectroscopy on the graphene found on the recycled carbon fibers to confirm the sheets (attached on the fibers) are indeed graphene.

(2) The reviewer suggested that the project study the effect of etched surface on the mechanical properties such as strength and modulus. The etched surface may have high stress concentration, leading to low strength.

Reviewer 3

This reviewer found minimal technical accomplishments described in the presentation and said that the Principal Investigator did not attend the poster session to explain any further accomplishments. The accomplishments are more of a description of the process under development. Development of the thermochemical process stated in the approach was achieved and micrographs show uniform fiber treatment. A result was that the carbon fiber surface area was increased by a factor of ten. There were no data presented for results of tensile strength tests, however, a graphic is displayed on the Relevance Slide that shows the relationship of the 10x improvement to increase in tensile strength. If the data on the graph are accurate, the 10x improvement still does not increase the strength to anywhere near the strength of continuously processed new carbon fiber. There is a statement on the Accomplishments Slide that preliminary results of tests indicate that the gained interfacial strength exceeds the tensile strength of the filaments, but there were no data provided to substantiate this statement.

Reviewer 4

This reviewer said that the project is projected as 80% complete; however, no significant data are provided. It is not difficult to believe that that some interfacial strength improvements are achieved via surface activation of the carbon fibers alone and this increase translates into some higher strength of discontinuous carbon fiber reinforced high-density polyethylene (HDPE) as others have demonstrated. However, it is not clear that the claimed interfacial strength gain exceeds the tensile strength of the filaments themselves as reported without data. One would expect some improvement in the reinforced HDPE strength with addition of adequately dispersed, but even non-treated carbon fiber. It would be useful to have such data to evaluate efficacy of the treatment process and especially data to support the pathway towards the project expectation of achieving 50% mass reduction at equal affordability.

Reviewer 5

This reviewer found that surface modification of the carbon fibers has been demonstrated but using a filamented form could limit the fiber volume fraction in the final composite.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer found that good collaborations were formed with Pennsylvania State University and support was received from the Composites Application Group and Carbon Conversions, Inc. A little more discussion of each collaborator's role in the project would be useful to see in the next AMR. It was stated that pilots with carbon fiber and composite companies were being actively pursued so that is a step in the right direction to get this technology closer to commercial adoption.

Reviewer 2

This reviewer said that the collaborations with Pennsylvania State University (PSU) and the Composites Applications Group have been going well. The partner Carbon Conversions provided recycled carbon fibers. The joint efforts will help scale up.

Reviewer 3

This reviewer noted that the project team consists of the company (H Quest Vanguard, Inc.) and a university (Pennsylvania State University) with consultation for commercialization from a company that coordinates between manufacturers and supply chain companies (Composites Applications Group). Carbon fiber for this project appeared to be donated from a commercial entity (Carbon Conversions, Inc.). The only collaboration seemed to be between the company and the university, which is limited collaboration for process development. According to the reviewer, involvement of an OEM or a Tier 1 supplier for coordination toward commercialization rather than a third party to advise on commercialization would benefit the project.

Reviewer 4

This reviewer found there to be really no discussion of the primary project team (Huest and PSU) interaction via roles and responsibility; Carbon Rivers provided some samples of recycled carbon fiber and Composites Applications Group provided some commercialization support.

Reviewer 5

This reviewer stated simply that the project partners are clearly defined

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer found that the future work is effectively planned in a logical manner. The future scope expansion into recycled carbon blacks makes this technology even more attractive to the automotive industry and the reviewer would like to see how that research pans out. The reviewer's only concern is with achieving all of the future work in the short time remaining in the project.

Reviewer 2

This reviewer said that the proposed future work makes sense. The project plans to scale up and extend the microwave plasma to recycled carbon blacks. This will help decarbonization.

Reviewer 3

This reviewer said that the future steps are pretty well described. At this point it is not clear to the reviewer whether the recycled carbon black mentioned in future work can achieve significant performance improvement and what cost would be assigned to recovered material, but it is laudable to target this approach rather than synthesizing the materials for this application. The reviewer questions, however, if the carbon black requires synthesis from methane, whether zero CO_2 emissions can still be claimed for the process. The reviewer suggested that future work needs to include additional characterization of the fiber itself (to assure minimal property degradation) and interfacial properties, as well as some early more detailed techno-economic modeling to evaluate cost-effectiveness of the solution package.

Reviewer 4

This reviewer said that the future steps appear adequate but a meaningful increase in composite performance should be established before increasing the scope of the project.

Reviewer 5

This reviewer pointed out that there were two slides for future work: (1) Future Steps and (2) Future Scope Expansion. The first one appears to be research that will be needed beyond the current project and the second appears to propose a new research effort for using the thermochemical process developed in this project to expand into carbon black in rubber products and away from carbon fiber and composites. The reviewer expressed not being aware of a VTO requirement for carbon black as it relates to composite materials. The future steps are clearly defined to scale up and commercialize the product from the current project. With the small amount of funds ($206,500) and the current project being 80% complete, the future steps would require significant additional funding. If adequately funded, it is very probable that the future work will achieve its targets, according to the reviewer.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the technology is aligned with VTO's mission to develop lightweight material solutions for automotive applications

Reviewer 2

This reviewer said that the project is relevant to the overall DOE objectives in that it focuses on vehicle light-weighting.

Reviewer 3

This reviewer found the project relevant and supportive of some of the overall VTO subprogram objectives for lightweight materials because it addresses the treatment of carbon fiber to improve its strength and the recyclability of carbon fiber to reduce the high costs associated with using virgin carbon fiber in composite materials.

Reviewer 4

This reviewer said that the project supports the VTO overall objectives. The microwave plasma presents a new route to carbon fiber recycling. This also help reintegrate end of life carbon fibers into the supply chain and decarbonization.

Reviewer 5

This reviewer said that, although the 50% mass reduction goal at equivalent cost is not fully supported, it appears that there are some opportunities for at least some performance improvements. However, findings of significant mass savings need to be supported with actual property data. It is not clear to the reviewer how specifically synthesized graphene-enriched carbon black (GCB) in combination with the equipment necessary to assure consistent deposition of energy and the GCB throughout a "web or mat" product stream of material starting out as an aligned form of fiber stuck together would not affect the cost. (The reviewer noted that the indicated cost of $0.25/kg for particle materials did not include equipment costs but still sounds low and said that it is hard to imagine that it would be lower than most sizings, as mentioned.)

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that, at 80% complete, there appear to be sufficient resources to finish all outstanding tasks.

Reviewer 2

This reviewer said that the resources are sufficient to achieve the remaining milestones.

Reviewer 3

This reviewer said that the funding of $206,500 for a company and a university for consulting is sufficient for this short-term project (less than 1 year). The contribution of raw materials from a carbon fiber manufacturer certainly helped with keeping the cost of the project low.

Reviewer 4

This reviewer said that H Quest Vanguard and its partners PSU, Composites Applications Group, and Carbon Conversions have the required resources for the project to achieve the stated milestones in a timely manner.

Reviewer 5

This reviewer said that the key remaining activity is getting at least some solid data and it sounds as if resources are adequate for achieving that goal in this phase.

Presentation Number: mat256
Presentation Title: Game Changing Resin/Coating/Adhesive Technology for Lightweight Affordable Composites
Principal Investigator: Scott Lewit, Structural Composites, Inc.

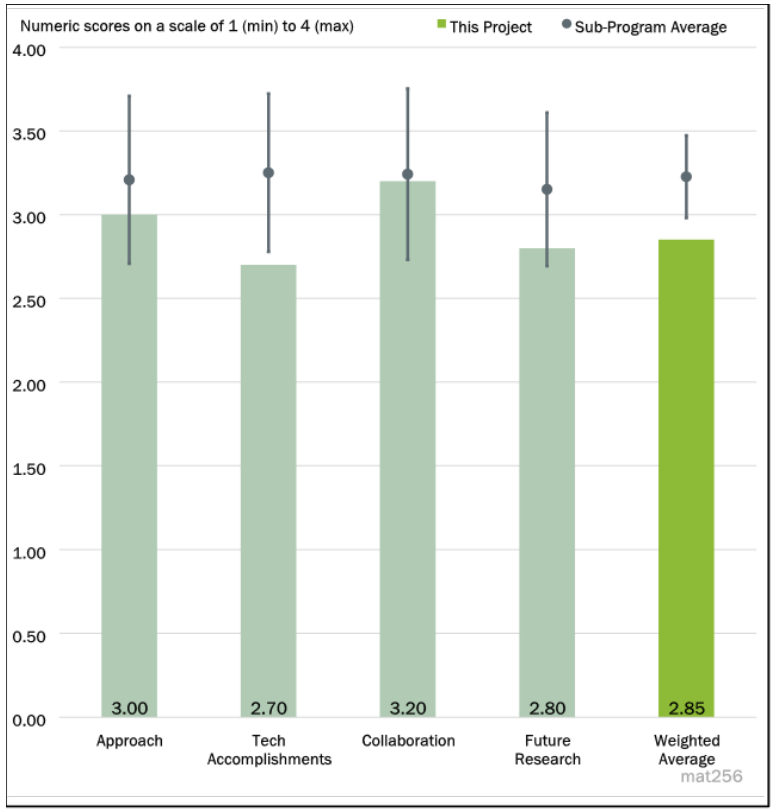

Figure 5-55 - Presentation Number: mat256 Presentation Title: Game Changing Resin/Coating/Adhesive Technology for Lightweight Affordable Composites Principal Investigator: Scott Lewit, Structural Composites, Inc.

Presenter

Scott Lewit, Structural Composites, Inc.

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

This reviewer found the idea of co-curable hybrid formable laminates to be excellent, but that not enough support was presented in the poster to justify the approach . The reviewer was not sure what kind of polyurethane was used in this work. Nonetheless, the reviewer said that the idea is great and has very good potential.

Reviewer 2

This reviewer said that the project has identified and addressed the technical barriers. The project was well designed and the timeline is reasonable.

Reviewer 3

This reviewer said that the approach is well-designed and well-planned to meet the technical barriers of metal/thermoplastic laminate structures. Images of the synthesized materials would be beneficial to the reviewer since it is a little unclear from the poster what the final product looks like. A little more visual representation of the project would help fully understand the approach and its results.

Reviewer 4

This reviewer said that the concept is sound but there were no data presented. The project data should be 75% complete even with COVID and supply chain issues. The reviewer believes that, because there are no data to substantiate the claims, it is difficult to decide if the project is well designed. The reviewer found the poster to be more like a white paper than a results presentation.

Reviewer 5

This reviewer pointed out that Structural Composites, Inc. (SCI) has issued press releases touting past development, introduction, and commercialization of the CoCure process. For this project, the target focus and approach are not at all clear, with a very general listing of potential general pathways to implementation, including: hybrid thermo set resin/metal hybrid composites laminates that are low-cost, high-performance, pre- and post-cure formable; get cost and adhesive and matrix; urethane, polyester, polyols; graphene, nano tubes, biofibers, starches, nano powders; and estimates of targeted cost or performance and how these might factor into approach.

According to the reviewer, there was no discussion of technical barriers to be addressed or estimates of targeted cost or performance and how these might factor into approach.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer pointed out that the project got a no cost extension. The project is on track and making progress toward the milestones. The reviewer suggested that DIC be used in mechanical testing to study the resin/coating/adhesive system with the goal to optimize the structure design.

Reviewer 2

This reviewer noted that the project was behind schedule due to supply chain issues and COVID-19 restrictions and a no cost extension has been requested, but the project is back on schedule. More data should be shown on the progress of the project to assess the mechanical property enhancements that were mentioned.

Reviewer 3

This reviewer found not enough data presented to support 75% completion of the project. The poster refers to 35% graphene containing compositions of "thermoplastic precursor of unsaturated polyester." The reviewer is not sure what is meant by "thermoplastic precursor of unsaturated polyester" and asks whether such composition will be able to wet high content (35%) of graphene?

Reviewer 4

This reviewer said that, without data, it appears there has been no technical progress. The team did state that it has achieved high volume, high performance, and low cost ultra-lightweight composite and hybrid materials but gave no examples and no metrics. The team could have shown data showing how the PU/nanoenhanced hybrid coating increases fracture toughness, hardness, Tg, flexural strength, flexural stiffness, and/or adhesive strength for starters.

Reviewer 5

This reviewer said that the project is projected to be 75% complete, but no data are provided to judge the progression toward the (unstated) goals. The reviewer understands that there were severe impacts from COVID and chose to give a Satisfactory score for that reason. The poster indicates that targets have been identified and fab and testing are underway based on plans for evaluating fiber bridging additives of graphene and carbon nano tubes, environmentally friendly bio fibers and starches dispersed in polyols, polyesters, and urethane resin blends for enhanced mechanical properties, among potentially others. One accomplishment that was mentioned was that compounding of a polyester with 35 % graphene has been achieved, but there was no mention of performance results or expectation for an achievement that seems well above levels of graphene most researchers target, considering typical cost and performance projections for that approach.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer said that the project had a good list of collaborators. It would helpful to mention each collaborator's role or contribution to the project.

Reviewer 2

This reviewer believed that the collaboration has been going well. The project team includes several industry partners. The reviewer suggested future research include collaboration with academy as well.

Reviewer 3

This reviewer pointed out that a large number of team members is listed. However, roles of team members are not clear. Also, the budget amount is very low compared to the size of the team.

Reviewer 4

This reviewer pointed out that the authors list Interplastics, Mainstream, Wabash, Applied Science, Carbon Rivers, MITO, TLC, Trinity, and THOR as partners. The reviewer believed that it is quite an achievement to have all of those partners on a relatively low funded program like this one but said that it would be interesting to see what each role is, however.

Reviewer 5

This reviewer found this difficult to evaluate as there is no indication, according to the reviewer, of how SCI is interacting with the very large numbers of partners listed other than brief mention of interest and discussion of large OEM partners and "Wabash is deployed using our Navy SBIR technology."

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer said that the topic and idea have tremendous future opportunity. Plenty of things can be done.

Reviewer 2

This reviewer noted that the proposed future research is built upon the success of Phase I. The targets are reasonable and achievable.

Reviewer 3

This reviewer said that the proposed future work focuses on securing commercial partners for further development, but it was unclear what future research was going to be performed within this project.

Reviewer 4

This reviewer said that it is difficult to have sound future work plans when there hasn't been much data, if any, developed over the original program to go off of. The reviewer believes that it would be technically significant if the team could show proof of their claims on this program before delving into future work.

Reviewer 5

This reviewer reiterated that only general comments about plans for completing this project (the development of enhanced resin properties, a low cost high performance adhesive, and metal alloy hybrids) and potential interest from others are provided, with lack of any specificity. Although it appeared to be mentioned in the context of the ongoing Wabash commercialization of the CoCure approach on their trailers, the comment about that focus now is reducing cost and weight should receive significant attention in future work related to this project.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the project is relevant to the overall DOE objectives to reduce the weight of vehicles to reduce fuel consumption.

Reviewer 2

This reviewer said that the combination of a gel-coat with a PU/nano-enhanced coating would aid not just the automotive industry but other industries as well. The potential of having a more durable surface coating, especially if it can achieve Class A, is beneficial in a variety of areas including appearance and abrasion/impact resistance.

Reviewer 3

This reviewer said the project supports the overall VTO objectives. The CoCure hybrid thermo set resin/metal hybrid composites laminates provide low cost, high energy efficient and lightweight materials for fuel efficient vehicles and EVs.

Reviewer 4

This reviewer said that the idea and the topic is relevant to VTO subprogram objectives.

Reviewer 5

This reviewer said that, although it appears that the ongoing commercialization is primarily for large trailers, one can see potential applications for other vehicles. However, cost-performance tradeoffs need to be better understood and efforts directed at specific barriers identified as part of that analysis.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer found the resources are sufficient to achieve the remaining milestones.

Reviewer 2

This reviewer said that SCI and its collaborators have sufficient resources for the project. The project is on track and will achieve the milestones in a timely manner.

Reviewer 3

This reviewer said that it is hard to evaluate adequacy of resources without a better understanding of specific goals and plans, but it sounds like there are adequate resources available to tackle key issues of not the broader technical interests that can be imagined for a new tool.

Reviewer 4

This reviewer said that it appears with the partners listed that sufficient resources exist to have a successful program but that has not been demonstrated yet or at least not revealed in this poster presentation.

Reviewer 5

This reviewer said that the budget is low. The team should pursue next phase to complete several tasks.

Presentation Number: mat257
Presentation Title: Changing the Design Rules of Rubber to Create Lighter Weight, More Fuel Efficient Tires
Principal Investigator: Kurt Swogger, Molecular Rebar Design

Presenter

Kurt Swogger, Molecular Rebar Design

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

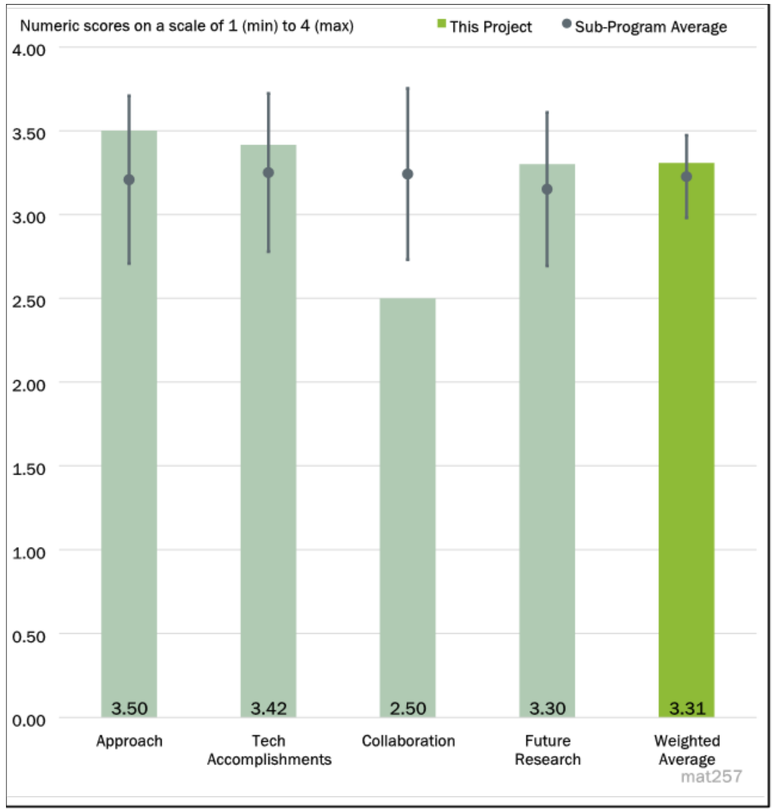

Figure 5-56 - Presentation Number: mat257 Presentation Title: Changing the Design Rules of Rubber to Create Lighter Weight, More Fuel Efficient Tires Principal Investigator: Kurt Swogger, Molecular Rebar Design

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

This reviewer said that the concept and approach are great. The reviewer's only concern was the cost of the compound, whether the team can assure availability of the MOLECULAR REBAR® (MR) at reasonable cost for large scale manufacturing.

Reviewer 2

This reviewer said that the work was a good approach to overcome the technical barriers of electric vehicle tires. With the faster wear rate of tires on EVs, this approach tackles a problem that needs to be solved. The work built off of prior success with substituting in carbon nanotubes in carbon-filled tires and translates it to silica-filled tires using a new chemistry. Overall, it was a well-designed and well-planned project.

Reviewer 3

This reviewer said that the team stated its technical targets and explained how it addressed them precisely in the poster. It demonstrated that the team was able to add carbon nanotubes to elastomers. Data shown corroborated its conclusions but there was no explanation of what tests were used to obtain the data.

Reviewer 4

This reviewer noted that improving tire properties to increase fuel efficiency and EV drive range is novel. The project identified and addressed the technical barriers. The project is well designed and the timeline is reasonable.

Reviewer 5

This reviewer said that the objectives are clearly identified and the activities appear laid out well to demonstrate how technology advancement translates towards meeting programmatic objectives and end-user benefits. The only thing missing is expected cost in commercialization and maybe it is too early to project.

Reviewer 6

This reviewer said that modification of the elastomer compounds for improved energy efficiency appears to be a logical approach to improve tire performance.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

This reviewer said that the data presented in the spider chart show significant progress compared to the state of the art. Achieving improved rolling resistance and abrasion resistance without compromising tear strength is a great accomplishment.

Reviewer 2

This reviewer noted that all technical accomplishments were met. Good enhancements in abrasion resistance, rolling resistance and density were reported using the carbon nanotubes. The reviewer questioned what the cost of adding the carbon nanotubes is, noting that it could be a trade-off to get the better performance.

Reviewer 3

This reviewer felt that, for the level of funding, the team made excellent progress and demonstrated its technical targets.

Reviewer 4

This reviewer said that the project has accomplished much. The results from Phase I are encouraging. The reviewer suggested that systematic friction and wear tests be carried out in the future study.

Reviewer 5

This reviewer pointed out that the project has been completed. Key data on abrasion resistance and rolling resistance have been acquired in this project and appear promising but it is not clear why that did not translate to cut and chip resistance.

Reviewer 6

This reviewer pointed out that the project team has demonstrated improvements in both rolling resistance and abrasion resistance, although there is no mention of the cost implications of the modified tire compounds.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer believed that, for this short project, collaboration is not really needed. Rather the applicant needs to protect IP.

Reviewer 2

This reviewer said that the Phase I project did not have collaboration, suggesting that future study involve collaboration with academics and the tire industry for scaling up.

Reviewer 3

This reviewer said simply that no other partners were included on this project.

Reviewer 4

This is no real collaboration discussed, but not sure at all that it is necessary considering the performer apparently has capability to formulate, produce samples, and test key attributes. Collaboration with manufactures should be included in a potential Phase 2 to assure commercialization relevance.

Reviewer 5

This reviewer said that no collaborators were listed on this project but it was less than a one year project.

Reviewer 6

This reviewer recounted that the authors stated that there was no collaboration due to the low level of funding.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer suggested that it would be beneficial to demonstrate this technology on actual tires and test tracks.

Reviewer 2

This reviewer found that Phase I has demonstrated promising results. The proposed future work makes sense and the targets are achievable.

Reviewer 3

This reviewer considered that the project is complete. This poster highlights the Phase II goal. It, however, lacks any commercialization plan.

Reviewer 4

This reviewer said that the outline was good, identifying most critical activities, including design a commercially viable prototype product form of the functionalized molecular rebar, for delivery into tire compound processes; develop guiding principles of use for the material, focusing on composite composition property relationships; and design, build, and test prototype tires, demonstrating that tires last at least 25% longer and make the EV at least about 7% more energy efficient.

However, the reviewer found key missing aspects to be the involvement of a commercialization partner and getting the true economics assessed. There are certainly tradeoffs in terms of IP control that need to be managed, but at least getting some commitment to interest in commercialization would be helpful and probably timely, considering data already produced.

Reviewer 5

This reviewer said that future research appears appropriate, albeit that the existing program of work is complete.

Reviewer 6

This reviewer said that the project has ended.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the technology under development fulfills VTO's mission to reduce energy consumption for improved fuel economy.

Reviewer 2

This reviewer said that the project is relevant to overall DOE objectives to improve electric vehicle efficiency by targeting improved wear resistance and energy efficiency of tires.

Reviewer 3

This reviewer said that the technology would have immediate impact in automotive and other sectors' tire technology. Additionally, this technology could improve the backbone of other chemistries of almost all fields.

Reviewer 4

This reviewer said that the project supports the overall VTO objectives and that the project is especially timely for increasing fuel efficiency and EV drive range.

Reviewer 5

This reviewer said that the project is relevant to the VTO subprogram objectives.

Reviewer 6

This reviewer said, citing these characteristics makes a clear tie to VTO programmatic goals: 20% improved rolling resistance = 7% gain in EV efficiency =1.5 cents/mile savings in EV operating costs and saving 32,300 MWh of electricity in 2030, which would be enough to power 1 million homes. The reviewer believed, although the poster did directly address it, that the claim of potentially achieving tires that last 25+% longer would have additional benefits in reducing landfill use, provided that this approach not impede recycling.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer noted that the project is short term and is 100% complete.

Reviewer 2

This reviewer said that the project has ended so no more resources are available.

Reviewer 3

This reviewer said that the team demonstrated technical competence and achievement with the level of funding provided and recommended that it work with other partners on future work, specifically for tire research in the near future and other areas, such as thermoplastic and thermoset resin chemistry, for later work.

Reviewer 4

This reviewer said that Phase I had the needed resources and future research may need to leverage the resources in academia and industry via collaboration.

Reviewer 5

This reviewer said that resources are sufficient.

Reviewer 6

This reviewer said that the project appears to have been successfully completed within the resources allocated. It did not appear that the amount of funding was in excess of what should have been necessary so resources were sufficient.

Presentation Number: mat258
Presentation Title: Hierarchical Micro/Nano Reinforced Multiscale Hybrid Composites for Vehicle Applications
Principal Investigator: Shawn Beard, Advent Innovations, LTD

Presenter

Shawn Beard, Advent Innovations, LTD

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

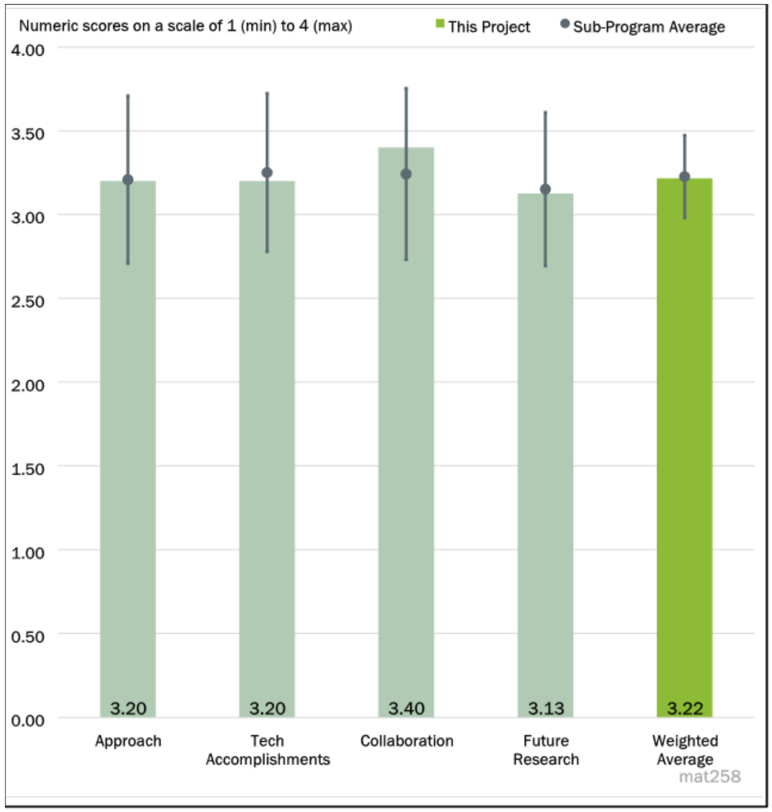

Figure 5-57 - Presentation Number: mat258 Presentation Title: Hierarchical Micro/Nano Reinforced Multiscale Hybrid Composites for Vehicle Applications Principal Investigator: Shawn Beard, Advent Innovations, LTD

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

This reviewer said that the approach is unique and promising to making high-strength fibers with self-sensing capabilities. Good processing images were presented to clearly convey the synthesis process and the resulting fibers. The reviewer would have like to have seen the composite properties compared to other fibers fabricated with the same process.

Reviewer 2

This reviewer said that Advent Innovations and Georgia Southern University (GSU) were teamed up to address the critical needs and technical barriers in polymer composites. The project was well designed and the timeline is reasonable.

Reviewer 3

This reviewer said that the approach, as described, has significant merit. However, it seems to be difficult to realize. With four gigapascal (GPa) strength fibers, the team accomplished only 600 megapascal (MPa) strength in unidirectional composites. The reviewer was not sure why the chopped fiber composites are very poor performing, exhibiting only 6-7 MPa failure strength.

Reviewer 4

This reviewer found that the project is well designed but the presentation does not directly specify what the fibers being coated are made of, Suggesting that it can possibly be assumed that only the nanofibers were being coated, but that was not stated directly. There is also a lack of real data. One stress vs strain curve was presented, but it did not specify which material was being tested or how. Additional testing curves were provided later, but did not show the properties calculated from them. It would be beneficial if the team could directly provide: the exact fiber composition; and the test results comparison between uncoated and coated fibers. The reviewer qualified these comments by noting that the objective was apparently mainly to synthesize these coated fibers, for later testing was mentioned as the 3rd objective.

Reviewer 5

This reviewer said that the approach was laid out with a logical general progression, but justification and specific targets were not identified. Lots of steps and material combinations were listed, along with a good many general objectives, such as increasing energy efficiency, increasing crashworthiness, reduced noise, vibration, and harshness, along with claims of 50% lower cost and 70% smaller carbon footprint, which are not immediately obvious (or supported at all in the poster). The reviewer expressed having been left to speculate that the potential baseline for comparison might be something like Spectra, another UHMWPE, and most of what the team is doing is compatibilizing with a potential composite matrix.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

This reviewer believed that, with potential follow-on funding, it would be important to perform a techno-economic analysis of this material. The reviewer stated that the coating process itself should not be cost intensive, but the material costs were the reviewer's major concern.

Reviewer 2

This reviewer said that Phase I was well done. The results are encouraging and the project milestones were all met.

Reviewer 3

This reviewer believed that the interfacial properties of the composites are likely not adequate and that that could be why both directional composites and discontinuous composites reinforced with fiber of strength 4 GPa exhibit poor mechanical properties.

Reviewer 4

This reviewer found that the progress hinges on the actual objectives. The team was successful in synthesizing the hybrid nanocomposite fibers (HyFi), but the reviewer was not exactly sure in which format. The poster did not mention the fiber length of these fibers, according to the reviewer. It showed the fabrication of test specimens, which meets the second objective. It did mention testing, but showed no test results, which would be necessary for excellent achievement.

Reviewer 5

This reviewer noted that the project is described as completed, yet, very, very little data was actually presented according to the reviewer. Fiber strength is stated as four GPa and strain-to-failure of 1300% (which the reviewer found questionable), but the data format does not reveal whether this is the one best fiber or an average of more than one. There are four "specimen" plots without much detail about the specimens (resin, fiber architecture, fiber fraction, etc.) provided in the presentation and backup slides. This seems inconsistent with Accomplishment page, which indicated: 1) Both long unidirectional fiber and chopped short fiber composite specimens were manufactured and tested; and 2) Specimens were made with various fiber resin ratios and architectures, including all-carbon fibers, all-HyFi fibers, and hybrid carbon-HyFi fibers. Thus, the plots do little to support the claim that "HyFi specimens exhibited high toughness and energy absorption properties".

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

This reviewer found that Advent Innovations and GSU formed a great team for this work.

Reviewer 2

This reviewer found good collaboration with Georgia Southern University, and that GSU's role in the project was clearly stated. Beyond Phase I, a well-organized list of collaborating partners was presented with each company's contribution to the future projects.

Reviewer 3

This reviewer said that the team showed excellent collaboration between Advent, GSU, Ford, and Steelhead Composites.

Reviewer 4

This reviewer said that the collaborations between Advent Innovations and GSU went well. The project team has been working with Ford and JTEKT North American Corporation, which helps scale up.

Reviewer 5

This reviewer said that the collaboration was not really described other than that GSU synthesized and processed fibers, including surface treatments, The reviewer apparently assumed that Advent made and tested composites. According to the reviewer, three other partners were listed but described as not participating until Phase 2. The reviewer was not sure that this is a major weakness at this point, but would like to see Ford involved to assess how much of this might be of real commercial interest to it considering that the project is focusing on PE fibers that may be expensive (especially with required post treatments) and likely to have stiffness/durability concerns as temperatures go up.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

This reviewer noted that the project has ended, but a plan for future work was laid out in a logical manner for further developing this research if additional funding is awarded.

Reviewer 2

This reviewer said that future work focusses on more process improvements, including scale-up, automation, and application of fiber treatments. The reviewer said that the presentation also mentioned testing but did not see real need to focus on testing much more to show the advantages of this technology . Finally, the plan is for running a cost analysis, which is perfectly in-line with DOE objectives.

Reviewer 3

This reviewer said that the proposed future research makes sense. The targets are reasonable and achievable.

Reviewer 4

This reviewer noted that the team is planning for scaled up R&D. However, it seems the composite compositions and interfaces are not optimized yet.

Reviewer 5

This reviewer said that the activities are largely logical but they are very broad and seem to be more focused on expanding targeted features than on actually getting key testing ad cost/performance assessments. It is clear to the reviewer that production higher than the fifteen grams listed as an accomplishment will be required to get some of these data but jumping ahead to piezoelectric properties (presumably for sensing) and standardizing the VARTM process before clarifying achievable properties and associated market interest is getting the cart before the horse, according to the reviewer.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

This reviewer said that the project supports the overall DOE objectives, specifically improving vehicle efficiency and enabling structural health monitoring capabilities.

Reviewer 2

This reviewer said that this is mostly a material development and can have advantages in many areas in the automotive industry and others.

Reviewer 3

This reviewer said that the project supports the overall VTO objectives. The developed polymer composites enable making vehicles lower cost, more energy efficient, smarter, and safer.

Reviewer 4

This reviewer said that this project is relevant to the VTO subprogram objectives.

Reviewer 5

This reviewer said that the project appears to be relevant, but needs focus on cost/performance tradeoffs with respect to specific applicability.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

This reviewer said that the project has ended so there are no remaining resources.

Reviewer 2

This reviewer said that the team utilized its resources well, with the exception of the need for more physical testing.

Reviewer 3

This reviewer found that Advent Innovations, GSU, Ford, and JTEKT North American Corporation have the necessary resources for accomplishing the proposed milestones and future research goals in a timely manner.

Reviewer 4

This reviewer said that the resources are sufficient.

Reviewer 5

This reviewer said that, without focused objectives and better planning, it is difficult to assess sufficiency of resources. The reviewer believed that there would probably not be enough resources for all of the general objectives listed, but if the objectives were sharpened, the resources probably would be sufficient.

Acronyms and Abbreviations

°C	Degrees Celsius
3-D	Three-dimensional
AI	Artificial intelligence
Al	Aluminum
AM	Additive manufacturing
AM	Additive manufacturing
AMR	Annual Merit Review
ANL	Argonne National Laboratory
APS	Advanced Photon Source
ASTM	American Society for Testing and Materials
BEV	Battery electric vehicle
CCF	Carbon-carbon fiber
CF	Carbon fiber
CFRC	Carbon fiber reinforced composite
CFRP	Carbon fiber reinforced polymer
CFTF	Carbon Fiber Technology Facility
cm	Centimeters
CNG	Compressed natural gas
CNT	Carbon nanontube
CO_2	Carbon dioxide
COVID-19	Coronavirus disease 2019
Cr	Chromium
CRADA	Cooperative research and development agreement
CTE	Coefficient of thermal expansion
Cu	Copper
Cu	Copper
CVD	chemical vapor deposition
DFT	Density function theory
DFT	Discrete Fourier transform
DIC	Digital image correlation
DOE	U.S. Department of Energy

EDAX	Energy dispersive X-Ray analysis
EERE	Energy Efficiency and Renewable Energy
EIS	electrochemical impedance spectroscopy
EMC	Electromagnetic compatibility
EMI	Electromagnetic interference
EV	Electric vehicle
Fe	Iron
FEA	Finite element analysis
FSLW	Friction-stir linear welding
FSP	Friction-stir processing
F-SPR	Friction self-piercing rivet
FSW	Friction-stir weld(ing)
GCB	Graphene-enriched carbon black
GHG	Greenhouse gas
GM	General Motors
GPa	Gigapascal
GSU	Georgia Southern University
HDPE	High-density polyethylene
HFR	High-rate friction rivet
HPC	High-performance computing
HPDC	High-pressure die casting
HTC	High temperature carbonization
HVR	High-velocity rivet
HyFi	Hybrid nanocomposite fibers
IACMI	Institute for Advanced Composites Manufacturing Innovation
ICE	Internal combustion engine
ICME	Integrated computational materials engineering
INL	Idaho National Laboratory
IP	Intellectual property
kg	Kilogram
ksi	Thousand pounds per square inch
LCA	Life-cycle analysis

LightMAT	Lightweight Materials Consortium
LLNL	Lawrence Livermore National Laboratory
LMCP	Light Metals Core Program
MAS	Micro-alloyed steel
MAT	Materials Technology Program
Mg	Magnesium
ML	Machine learning
mm	Millimeter
MMC	Metal matrix composite
Mn	Manganese
MPa	Megapascal
MPa	Megapascal
MR	MOLECULAR REBAR®
MRL	Manufacturing Readiness Levels
msi	Million pounds per square inch
MSU	Mississippi State University
MTT	Materials Technical Team
Mw	Molecular weight
MWh	Megawatt hour
NBR	Nitrile rubber (nitrile-butadiene rubber(
Ni	Nickel
nm	Nanometer
NREL	National Renewable Energy Laboratory
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
OSU	Ohio State University
PAEK	polyaryletherketone
PAG	polyalkylene glycols
PAN	Polyacrylonitrile
PE	Polyethylene
PEAK	Polyaryletherketone
PI	Principal Investigator

PNNL	Pacific Northwest National Laboratory
PP	Polypropylene
PSU	Pennsylvania State University
PU	Polyurethane
PUSP	Power ultrasonic surface processing
PVC	Polyvinyl chloride
PVDF	Polyvinylidene fluoride
PVP	Polyvinylpyrrolidone
R&D	Research and development
SBIR	Small Business Innovation Research
SBIR	Small Business Innovation Research
SCI	Structural Composites, Inc.
SEM	Scanning electron microscopy
ShAPE™	Shear Assisted Processing and Extrusion
SPH	Smoothed Particle Hydrodynamics
SPR	Self-piercing rivet
SRNL	Savannah River National Laboratory
STEM	Scanning transmission electron microscopy
SURF	Scale-Up Research Facility
TEA	Techno-economic analysis
TFP	Tailored fiber placement
T_g	Glass transition temperature
TiB_2	Titanium diboride
TPM	Thermo-Pseudo Mechanical
TRL	Technology Readiness Level
TuFF	Tailorable universal feedstock for forming
U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability
UAM	Ultrasonic additive manufacturing
UCC	Ultra-conducting copper
UCLA	University of California at Los Angeles
UHMWPE	Ultra-high-molecular-weight polyethylene

UNT	University of North Texas
USAMP	U.S. Automotive Materials Partnership
UT	University of Tennessee
UV	Ultraviolet
VARTM	Vacuum assisted resin transfer molding
VFAW	Variable frequency arc welding
VTO	Vehicle Technologies Office
Zn	Zinc
Zr	Zirconium
µm	Micrometer

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6. Technology Integration

The Vehicle Technologies Office (VTO) supports research, development, deployment, and demonstration (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. The office's investments leverage the unique capabilities and world-class expertise of the national laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies and systems (including automated and connected vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement); combustion engines to reduce greenhouse gas (GHG) emissions; and technology deployment and integration at the local and state level. In coordination with the other offices across the Office of Energy Efficiency and Renewable Energy (EERE) and the U.S. Department of Energy (DOE), the Vehicle Technologies Office advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

The VTO Technology Integration (TI) subprogram covers a broad technology portfolio that includes alternative fuels (e.g., advanced biofuels, electricity, hydrogen, renewable natural gas) and energy efficient mobility systems. The successful deployment of these technologies can support the decarbonization of the transportation sector, strengthen national security through fuel diversity and the use of domestic fuel sources, reduce transportation energy costs for businesses and consumers, address the needs of underrepresented communities, and support energy resiliency with affordable alternatives to conventional fuels that may face unusually high demand in emergency situations. At the national level, the Technology Integration Program offers technical assistance, information resources, online training, and an array of data and analysis tools. At the local level, Clean Cites coalitions leverage these resources to create networks of community stakeholders and provide hands-on technical assistance to fleets.

The Technical Assistance activities support projects to provide information, insight, online tools, and technology assistance to cities and regions working to implement alternative fuels and energy efficient mobility technologies and systems. Projects will; demonstrate proof-of-concept of alternative fuel/advanced technology vehicles, charging infrastructure, new mobility systems for goods and people movement and modeling and simulation.

The Data Collection and Dissemination activity will collect and provide objective, unbiased data, information, and real-world lessons learned to inform future research needs and provide fleets and local decision makers with a suite of resources to identify and address technology barriers. This includes projects to disseminate data, information, and insights.

The EcoCar Mobility Challenge challenges 12 university teams to apply advanced powertrain systems, as well as connected and automated vehicle technology to improve efficiency, safety, and consumer appeal. In FY 2022, student teams completed and implemented their vehicle design through hardware development and engineering.

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	Objectives	Approach	Accomplishments	Collaboration	EEEJ	Weighted Average
ti126	Twin Cities Electric Vehicle Community Mobility Network	Lisa Thurstin (American Lung Association)	6-5	3.75	3.63	3.13	3.63	3.75	3.46
ti127	Mid-Atlantic Electrification Partnership	Al Christopher (Virginia Department of Mines, Minerals, and Energy)	6-9	3.38	3.13	3.00	3.38	3.38	3.18
ti128	Western Smart Regional Electric Vehicle Adoption and Infrastructure at Scale	James Campbell (PacifiCorp)	6-13	3.50	3.25	3.00	3.25	3.75	3.25
ti129	Helping America's Rural Counties Transition to Cleaner Fuels and Vehicles	Ken Brown (Transportation Energy Partners)	6-16	3.75	3.25	3.00	3.50	3.50	3.30
ti130	VOICE-MR:Vocation Integrated Cost Estimation for Maintenance and Repair of Alternative Fuel Vehicles	Arvind Thiruvengadam (West Virginia University)	6-19	3.50	3.17	2.83	2.83	2.83	3.03

ti131	DRIVE (Developing Replicable, Innovative Variants for Engagement) for Electric Vehicles (Evs) in the USA	Jonathan Overly (East Tennessee Clean Fuels Coalition)	6-23	4.00	3.50	3.50	3.83	2.83	3.57
ti132	The National Fire Protection-Association (NFPA) Spurs the Safe Adoption of Electric Vehicles through Education and Outreach	Andrew Klock (National Fire Protection Association)	6-26	3.50	3.38	3.63	3.50	2.75	3.45
ti134	Delivering Clean Air in Denver: Propane Truck and Infrastructure in Mail Delivery Application	Bonnie Trowbridge (Drive Clean Colorado)	6-29	3.50	3.38	3.00	3.50	3.38	3.26
ti135	Advancing Climate & Innovation Goals of Memphis & Shelby County: Electrification of Key Fleet Vehicles to Capture Cost Savings and Climate Benefits	Leigh Huffman (Shelby County)	6-33	3.13	2.88	2.63	3.13	2.38	2.80
ti136	Zero Emission Freight Future	Megan Stein (Clean Fuels Ohio)	6-38	3.63	3.25	3.50	3.38	3.13	3.43

ti137	Cold-Weather Operation, Observation and Learning Electric Vehicles	Lisa Thurstin (American Lung Association)	6-42	3.38	3.38	3.13	3.25	3.25	3.25
ti138	Demonstrating Electric Shuttles for the New Orleans Region	Elizabeth Davey (Tulane University)	6-46	3.30	3.20	2.80	3.10	2.90	3.02
ti139	Pilot Heavy-Duty Electric Vehicle (EV) Deployment for Municipal Solid Waste Collection	Shaina Kilcoyne (Municipality of Anchorage)	6-50	3.30	3.30	2.90	3.20	3.20	3.12
ti140	St. Louis Vehicle Electrification Rides for Seniors	Connor Herman (Forth Mobility)	6-54	3.30	3.20	3.70	3.50	3.70	3.50
Overall Average				**3.49**	**3.28**	**3.12**	**3.35**	**3.19**	**3.26**

Presentation Number: ti126
Presentation Title: Twin Cities Electric Vehicle Community Mobility Network
Principal Investigator: Lisa Thurstin, American Lung Association

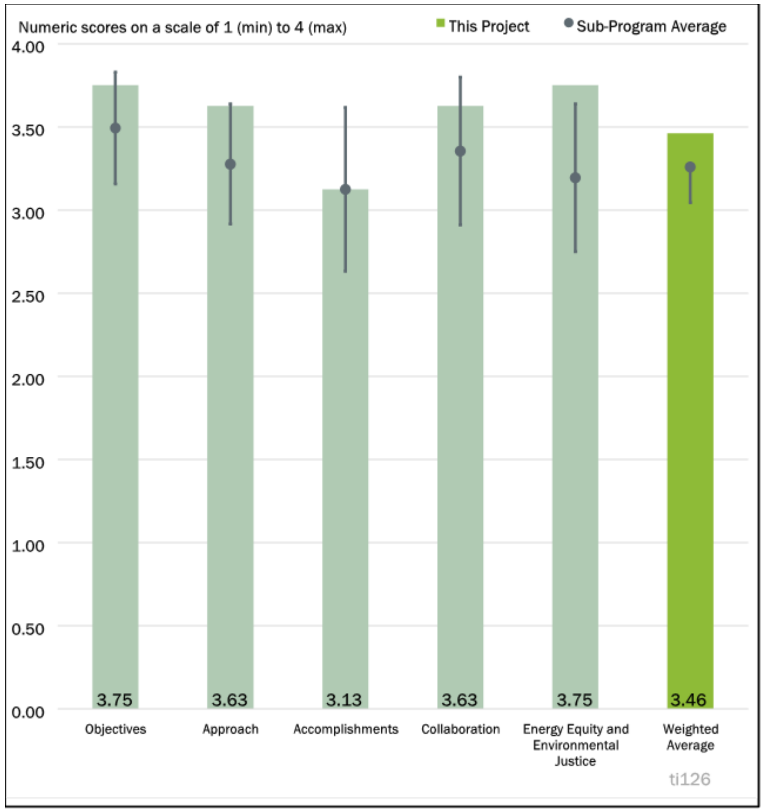

Figure 6-1 - Presentation Number: ti126 Presentation Title: Twin Cities Electric Vehicle Community Mobility Network Principal Investigator: Lisa Thurstin, American Lung Association

Presenter

Lisa Thurstin, American Lung Association

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: *Project Objectives—Please provide comments on this project's degree of support for the overall Technology Integration (TI) objectives of improving fuel diversity, increasing local resiliency, and reducing greenhouse gas emissions through increasing alternative fuel use and transportation efficiency.*

Reviewer 1

The reviewer stated that this is a leading example of building out community level electric car sharing, and added that it is also a leading example of right of way charging in collaboration with cities. Overall, the reviewer found it to be a very exciting project with a lot of potential.

Reviewer 2

The reviewer found several strengths in the project, including its focus on electric vehicle (EV) and electric vehicle supply equipment (EVSE) deployment, the creation of a community-focused mobility network, and education and outreach to car-share customers and community-based organizations is strongly aligned with TI objectives. The reviewer also found the incorporation of cost-effective renewable electricity (via utility wind program) to be a strong component of the project that was well-aligned with DOE objectives. The reviewer added that the project will indirectly help inform an adjacent project the principal investigators (PI) is conducting that focuses on EV cold weather performance.

Reviewer 3

The reviewer stated that this project helps to complete all four objectives. It involved improving fuel diversity and increasing alternative fuel vehicle use through the deployment of electric vehicles and charging stations and increased local resiliency through adding 70 renewably powered curbside EV spots in Saint Paul and Minneapolis. The reviewer added that the project created transportation efficiencies through focusing on carshare—a way to target many individuals that promotes moving away from individual car ownership.

Reviewer 4

The reviewer commented that dual use stations (carshare+ public) maximize accessibility for all community members and found that the integration of the carshare program with other transit modes improves overall transportation efficiency by encouraging transit use while allowing car access when needed for specific trips.

Question 2: *Project Approach-Please comment on this project's approach for integrating advanced transportation technologies and practices to solve real-world challenges.*

Reviewer 1

The reviewer commented that this project addresses bringing electric vehicles in an affordable manner (via carsharing), to communities not previously served. It also focuses on solving the issue of how carsharing can work, and how social norms or technology can solve the problem of keeping cars in carsharing programs charged. The reviewer further noted that the project brings electric vehicles which are often more expensive to traditionally underserved populations that might not be able to or willing to afford electric vehicles. The reviewer remarked that the funding partners make the project sustainable beyond the period of performance which makes the project outlast even the initial deployment of vehicles and stations.

Reviewer 2

The reviewer found that despite challenges related to COVID, the project successfully deployed charging infrastructure, while managing multiple local partners including municipalities, the utility and vehicle and charging station providers to make the project happen.

Reviewer 3

The reviewer found that the project approach involves a fairly robust multi-unit dwelling (MUD) vetting/selection criteria process, and noted that the EV carshare service includes parking, which is a big incentive for attracting new urban users. The reviewer also cited as a strength that DC fast charging is included in the project, and will be right-sized to fit the urban/boulevard settings scoped within the project.

The reviewer posited that there could be potential conflicts between different types of station users (carshare clients vs. public users), and noted that the presentation didn't really discuss how this might be mitigated.

Reviewer 4

The reviewer found the combination of public and affordable housing, and one way and two way carshare, along with public charging, to be quite innovative. The reviewer stated that this is also a leading example of engaging cities as full partners in providing carshare, and in providing public right of way charging. The reviewer commented that providing shared EVs at affordable housing is a great way to ensure charging is used, and provides benefits to the local residents and community when not simply built as an amenity that may drive gentrification.

The reviewer found the major concern to be the project's long term business model. The reviewer indicated that the statistic of "300 to 400 uses per month" equates to approximately three to four rentals per car per month, yet profitable private carshares typically see usage more like five hours per car per day. The reviewer noted that that is an order of magnitude growth needed to get close to breakeven. The reviewer stated that long term public funding may be inevitable, but if the service is not being heavily used and showing progress towards breakeven, it risks losing public and political support. The reviewer added that it is also less replicable or scalable to other regions at that point. The reviewer commented that, to be fair, nobody has this problem solved, but the project could take this challenge more seriously and move towards self- sufficiency.

Question 3: *Project Accomplishments and Progress-Please comment on the project's progress and significant accomplishments to date.*

Reviewer 1

The reviewer stated that supply chain woes for charging, delays with permitting, etc. are inevitable right now, but, given the many challenges faced, the project seems to have made great progress. The reviewer added that the recall of Chevy Bolts has set back many projects recently as well. The reviewer was particularly impressed that the project has moved along as well as it has given all the moving parts and involvement of multiple partners, including two cities installing hardware in their rights of way.

Reviewer 2

The reviewer commented that, despite charging station installations taking years, challenges with recalls, microchip shortages, and coordination between the groups etc. this project has already seen much success, and noted that 30 Level 2 hubs have been installed or commissioned, 12 DC Fast locations have been confirmed and 12 of 50 vehicles for use by residents of MUDs have been secured. The reviewer remarked that, although the project has more than 50%-60% of installs to go, it has already created the basis for a highly visible and sustainable EV ecosystem in Saint Paul. The reviewer noted that this project has momentum and partners to amplify its message.

Reviewer 3

The reviewer commented that the delays in vehicle deliveries have limited the impact of the carshare vehicles, although early data does indicate the potential for strong usage. The reviewer recommended that the impacts be further evaluated when the project has been in use for longer.

Reviewer 4

The reviewer remarked that vehicle and EVSE procurements have reasonably progressed, despite supply chain constraints.

The reviewer observed that it seems that making progress in securing multi-unit dwelling (MUD) partners has been a challenge, in part due to their reluctance to commit parking spaces and staffing resources to support EV charging, and that the project would have benefited from including MUD partners as direct project participants. The reviewer found the number of outreach events held to be somewhat low at this point in the project (8 out of 25 held).

Question 4: *Collaboration and Coordination Among Project Team—Please comment on the level of collaboration within the project team and the degree to which the project team has identified and leveraged the proper connections to achieve its project goals.*

Reviewer 1

The reviewer remarked that there seems to be an impressive level of collaboration and alignment between the cities and other stakeholders in this project.

Reviewer 2

The reviewer found that the project demonstrated good collaboration among strong industry, local government, fleet, utility, community organizations and Clean Cities partners.

The reviewer commented that the project would have benefited from having MUD partners at the onset of the project.

Reviewer 3

The reviewer noted that this project involved coordination between many groups, and included working with the Utility (Xcel Energy), which likely involved paperwork and advanced planning, working with HOURCAR, identifying drivers, and working with Saint Paul to identify MUDs and garage locations.

Reviewer 4

The reviewer commented that the project involved coordination among partners including municipalities, the utility and vehicle and charging station providers to make the project happen, and noted that the leases were designed so the cities will own and operate by the end of the project.

Question 5: *Energy Equity and Environmental Justice Project Contribution-Please provide comment on the contribution of this project to energy equity and environmental justice by ensuring the project benefits underserved and overburdened communities and does not cause increased burdens to these communities.*

Reviewer 1

The reviewer noted that project locations were selected using energy and environmental justice (EEJ) metrics, and that carshare programs have a sliding scale based on user income. In addition, the reviewer commented that the availability of program materials in multiple languages and translations services makes the program accessible to all linguistic groups.

Reviewer 2

The reviewer noted several strengths including that the project will provide charging for both car sharing service and non-carshare users, making the infrastructure open to the widest number of users in the community. Further, a large share of EV hub sites are sited or planned to be located in areas where 50% or more of residents are people of color.

Reviewer 3

The reviewer commented that this project found an innovative way to bring charging stations to underserved communities, in the form of an app that makes 24/7 translation and interpretation services available and that has a relatively fast verification and member approval process.

Reviewer 4

The reviewer remarked that East Metro Strong seems to be a solid community partner, but that beyond that, it is not clear how much engagement and support there is with community based organizations. In the selection of multifamily housing locations, the criteria seemed to emphasize city priorities. The reviewer commented that the criteria did not include more issues like the need for residents to commute to work, history of redlining or gentrification, etc.

The reviewer commented that more funding and capacity for the project to actively recruit and inform community housing operators, and more funding and support to the housing operators for staffing and outreach was needed. The reviewer added that the project is counting on community based organizations to dedicate staff time and resources to supporting this program, when best practice would be to provide resources to those organizations to ensure this project does not place further burdens on them.

The reviewer noted that the project did not seem to intentionally work with minority and women owned business enterprise (MWBEs) in the acquisition and installation of the charging infrastructure.

Presentation Number: ti127
Presentation Title: Mid-Atlantic Electrification Partnership
Principal Investigator: Al Christopher, Virginia Department of Mines, Minerals, and Energy

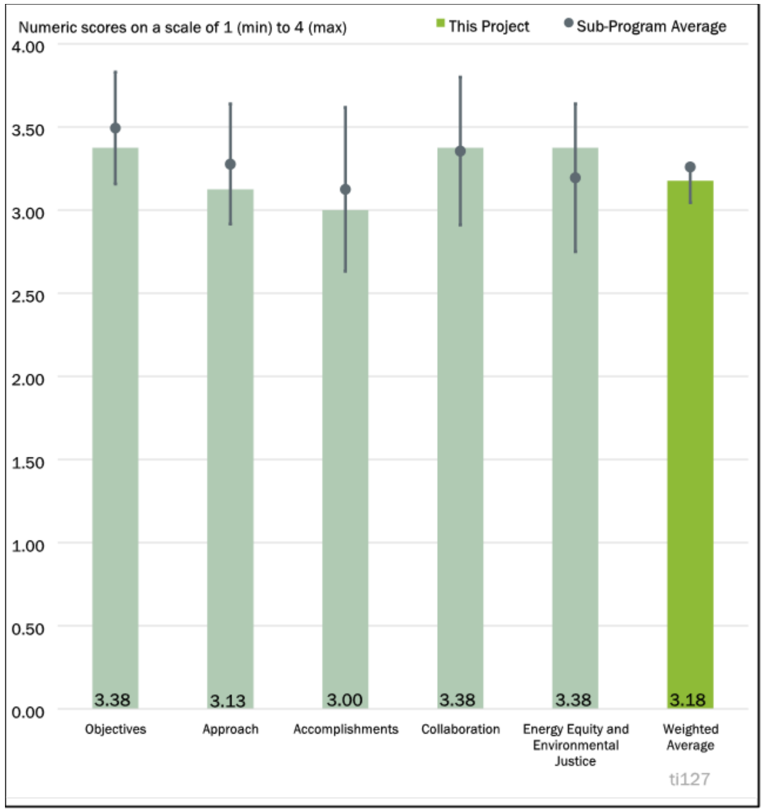

Figure 6-2 - Presentation Number: ti127 Presentation Title: Mid-Atlantic Electrification Partnership Principal Investigator: Al Christopher, Virginia Department of Mines, Minerals, and Energy

Presenter

Al Christopher, Virginia Department of Mines, Minerals, and Energy

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: *Project Objectives—Please provide comments on this project's degree of support for the overall Technology Integration (TI) objectives of improving fuel diversity, increasing local resiliency, and reducing greenhouse gas emissions through increasing alternative fuel use and transportation efficiency.*

Reviewer 1

The reviewer noted that the project is developing an electrification ecosystem focused on private light-duty EVs, rideshare EVs, freight, and transit electrification throughout the mid-Atlantic, which is strongly aligned with DOE/VTO/TI objectives.

The reviewer commented that Argonne National Laboratory-developed tools (generated under the project) can be more widely used/leveraged outside the project.

Reviewer 2

The reviewer stated that the project generally meets the overall objectives of improving fuel diversity, increasing local resiliency, and reducing greenhouse gas emissions through increasing alternative fuel use and transportation efficiency. The reviewer noted that integrating EVs helps with fuel diversity, and ensures that more community members with EVs look to drive their electric vehicles to Baltimore/Washington International Airport (BWI), versus rideshare with an internal combustion engine vehicle. Solar stations help bring more resiliency.

Reviewer 3

The reviewer commented that the project includes a number of different applications for electric vehicles and charging. The reviewer noted that project impacts were somewhat limited due to pandemic related delays to vehicle delivery and infrastructure completion.

Reviewer 4

The reviewer noted that the project seems to be largely a straightforward installation of EVSE, provision of vehicles, and related outreach activities, a broad approach that includes a little bit of everything, but stated that it is not clear there is a compelling or innovative underlying approach or theory of change about barriers the project is trying to overcome. The reviewer added that it seems to be a very general project to support and advise Virginia and some other mid-Atlantic states about EV matters. The reviewer posited that some of this may be a function of the presentation, which was lacking in details, some of which came out during the oral presentation.

The reviewer indicated a need for a stronger understanding of what systemic barriers the project is attempting to overcome, what tools it is working to develop, and what systems change it is trying to achieve in order to "build an EV ecosystem" in the region.

Question 2: *Project Approach-Please comment on this project's approach for integrating advanced transportation technologies and practices to solve real-world challenges.*

Reviewer 1

The reviewer commented that the project approach involves strong innovative components, including a solar canopy charging deployment/demonstration station targeted towards workplace charging, and that it includes outreach components that are important for helping to drive interest and infrastructure use.

The reviewer remarked that some of the tool's development seems disjointed from the Mid-Atlantic focused activities, added that the degree to which station maintenance and uptime/reliability will be covered/addressed is not really discussed or known.

Reviewer 2

The reviewer stated that by focusing on BWI, the project would serve to help BWI and increase traffic from farther distances than would otherwise have been able to drive and fly from BWI; however, it is not necessarily the local community that would go to local retail stores. The reviewer noted that the project did add 25 vehicles to a rideshare which certainly helps reduce greenhouse gases (GHGs) and increases local resiliency.

Reviewer 3

The reviewer noted that the project addresses a number of different facets of transportation electrification; however, this multi-pronged approach may limit the impact in any single area.

Reviewer 4

The reviewer stated that it is not clear how the project is integrating technologies to overcome real world challenges, other than simply providing some charging, vehicles, and outreach. The reviewer added that the presenter talked about it as a "miniature laboratory of democracy," but it was not clear from the presentation what sort of tools or playbooks will be developed to facilitate scaling or replication beyond the project period. The reviewer acknowledged, however, that the project does seem to be starting to show success in delivering concrete benefits (vehicles and charging) across the region.

Question 3: *Project Accomplishments and Progress-Please comment on the project's progress and significant accomplishments to date.*

Reviewer 1

The project exceeded goals on outreach and laid the groundwork for widespread infrastructure deployment.

Reviewer 2

The reviewer commented that this project involved educating at more than 15 in-person and online outreach events held (8 were planned), which shows this group is getting the word out, and added that the group selected project partners in minority groups or those that would truly be able to understand what an equitable transition should look like. The reviewer opined that selecting a university as a place to install a renewable solar station serves to get the word out in a big way and encourage students to go electric, and that with over 21,000 students, James Madison University was an ideal location to choose. The reviewer speculated that, if popular, it may encourage University officials to get more stations.

Reviewer 3

The reviewer stated that the project accomplishments made to date are impressive, particularly the outreach and education tasks. The reviewer added that charging station and vehicle deployments have been slower, but this is presumably due to post-pandemic supply chain constraints. Strengths included that some of the first revenue-generating stations in WV were installed under this project, and the stations installed at BWI are NEVI-compliant.

The reviewer observed that the project is underspent by quite a bit, and assumed this is due to vehicle and equipment procurement delays, although this wasn't explained during the presentation.

Reviewer 4

The reviewer observed that, even with the extension, this project seems to be well behind schedule, with about 10% of funding expended with 25% of project period past. The reviewer expressed sympathy regarding the supply chain delays, vehicle acquisition challenges, and delays of working with public agencies, but added that it seems the project also brought some of this on itself through design, e.g. by focusing on working with cities to install charging and serve as site hosts. The reviewer opined that it sounds like the project has lacked focus and has been pulled into providing whatever support the region wants (e.g., help with National Electric Vehicle Infrastructure [NEVI] planning.), which shows responsiveness to the communities served, but also seems to distract the team from achieving the core goals outlined in the project proposal.

Question 4: *Collaboration and Coordination Among Project Team—Please comment on the level of collaboration within the project team and the degree to which the project team has identified and leveraged the proper connections to achieve its project goals.*

Reviewer 1

The reviewer noted that the project has forced utilities from significantly different jurisdictions to talk and work together on numerous key issues, and added that the team includes a diverse set of community, industry, lab, utility, end-user and Clean Cities partners that have worked well together in carrying out accomplishments to date.

Reviewer 2

The reviewer commented that research informed education and vice versa. The reviewer noted that the team could have brought in the analysis collaboration and even EV charging station stakeholders such as utilities and vendors to help in their education material, but that, overall, they did a great job. The reviewer found that the project does not address the affordability issue of electric vehicles and the inability of certain groups to access them, but that the analysis piece allows project partners to identify charging gaps and assess their location in relation to underserved communities, which could help when entities do have funding in the future.

Reviewer 3

The reviewer found that the large number of stakeholders involved reflects positively on the coordination abilities of the project staff; however, it was not clear how much interaction there is between different aspects of the project. For example, does the ride and drive outreach contain information on the infrastructure that is being deployed?

Reviewer 4

The reviewer stated that the roles of team members are not entirely clear. The reviewer added that EVNoire and some Clean Cities coalitions seem to be doing some regional outreach, though details are unclear, and it is not clear how they are engaging with other stakeholders in the region that influence vehicle purchase and charging installation decisions.

The reviewer noted that the labs seem to be working together fairly well to do modeling and studies, but that it is not entirely clear how those are then being used by states or utilities in the region.

Question 5: *Energy Equity and Environmental Justice Project Contribution-Please provide comment on the contribution of this project to energy equity and environmental justice by ensuring the project benefits underserved and overburdened communities and does not cause increased burdens to these communities.*

Reviewer 1

The reviewer commented that the project provides some analysis that can serve as starting points for NEVI recipients and law makers when thinking of how to disperse funding, stations and resources. The reviewer added that the study addresses carsharing as one method of getting electric vehicles into use by all members of a society. The reviewer noted that there are still issues with how to fully address funding inequities, but that law makers and others can certainly use this project as a great starting point. Great work!

Reviewer 2

The reviewer commented that project partners have working relationships with Historically Black Colleges and Universities (HBCUs) and the National Society of Black Engineers.

The reviewer noted that infrastructure placement under the project will be informed by Argonne's Energy Zones Mapping Tool (EZMT), taking some of the same approach and data being used for the development of the Electric Vehicle Charging Justice 40 Map.

Reviewer 3

The reviewer commented that the project features strong outreach to historically underserved populations, as well as infrastructure placed in EEJ identified communities.

Reviewer 4

The reviewer stated that the modeling work / EZMT is interesting and seems beneficial, as does the recent case study, but that the project could be doing more to share and promote those results. The reviewer commented that the sample outputs provided seem a bit off, if they are estimating household transportation costs of less than 5%, which seems shockingly low.

The reviewer observed that the connection with HBCUs is interesting but not well explained. No details were presented on how many such events were organized, how many people participated, etc. The reviewer added that the E-Mobility Equity conference that was noted was funded by other sources, and was national in scope. That conference did create an opportunity to talk about some of the work this project is doing—but it was not part of this project.

Presentation Number: ti128
Presentation Title: Western Smart Regional Electric Vehicle Adoption and Infrastructure at Scale
Principal Investigator: James Campbell, PacifiCorp

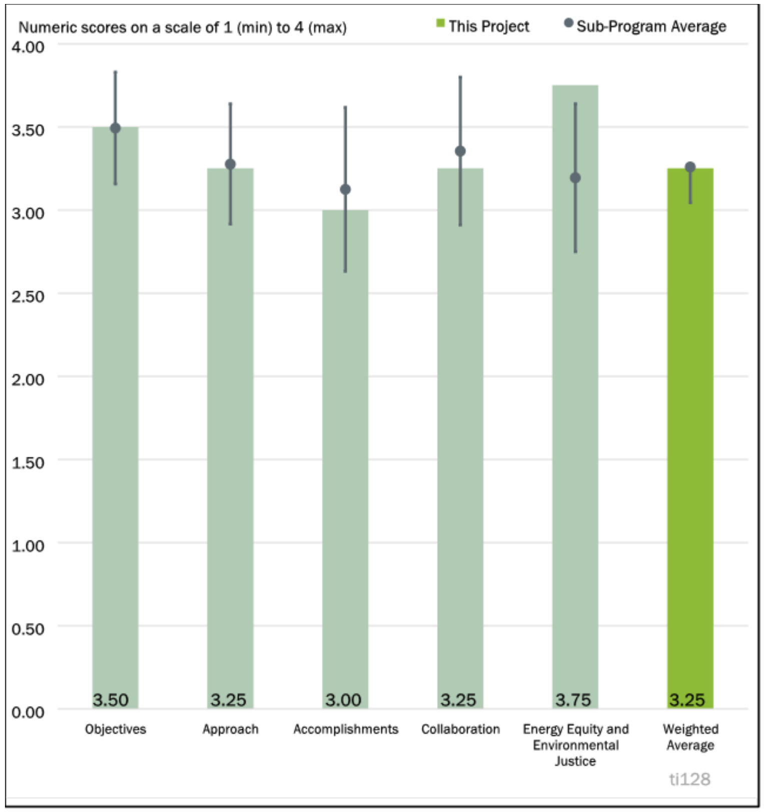

Figure 6-3 - Presentation Number: ti128 Presentation Title: Western Smart Regional Electric Vehicle Adoption and Infrastructure at Scale Principal Investigator: James Campbell, PacifiCorp

Presenter

James Campbell, PacifiCorp

Reviewer Sample Size

A total of two reviewers evaluated this project.

Question 1: *Project Objectives—Please provide comments on this project's degree of support for the overall Technology Integration (TI) objectives of improving fuel diversity, increasing local resiliency, and reducing greenhouse gas emissions through increasing alternative fuel use and transportation efficiency.*

Reviewer 1

The reviewer found the project to be highly aligned with VTO/TI objectives as it addresses five timely/relevant focus areas: highway EV corridors, urban EV mobility, freight and port electrification, community and workplace charging, and EV access and training for underserved regions. The reviewer added that energy resiliency is a key component of the project that strongly aligns with DOE objectives.

Reviewer 2

The reviewer stated that this project supports charging deployments addressing multiple users in both urban and rural areas, and shows the capabilities of electric transportation in a variety of use cases.

Question 2: *Project Approach-Please comment on this project's approach for integrating advanced transportation technologies and practices to solve real-world challenges.*

Reviewer 1

The reviewer stated that multiple approach areas broaden project impacts to corridors, underserved communities, and freight issues, among others.

Reviewer 2

The reviewer stated that the effort is focused on procuring the right vehicles with best available range (for eCarshare), and that coupling the carshare service with affordable housing and targeting users that would benefit from not needing a car to start with, or would have issues getting insurance, etc., is a smart approach. The reviewer added that coupling electrified rail with medium-duty/light-duty (MD/LD)/micro-mobility charging (intermodal hub) is also an smart and innovative approach.

The reviewer expressed the view that there perhaps should have been a better plan for approaching National Park Managers (who are apparently the gatekeepers to park coordination and vary in terms of their interest and accessibility), at the onset of the project. Additionally, the project may be somewhat unwieldly, as it is seeking to do a lot, and perhaps too much.

Question 3: *Project Accomplishments and Progress-Please comment on the project's progress and significant accomplishments to date.*

Reviewer 1

The reviewer noted that the project has completed the modeling and planning stages and is now well into deployment, data collection on subprojects will help to further quantify the impacts of these effort, and the use of NREL's EVI-Roadtrip model was good.

Reviewer 2

The reviewer remarked that the project has 50 transportation network company (TNC) drivers engaged and providing EV use data, which is excellent, and noted that the project has made significant progress in data collection activities across a wide range of sub-project areas, including TNCs, inland port electrification, airport electrification, and workplace charging.

The reviewer commented that the project's budget seems underspent, and noted that this was not explained during the presentation, nor was the plan to catch-up on progress.

Question 4: *Collaboration and Coordination Among Project Team—Please comment on the level of collaboration within the project team and the degree to which the project team has identified and leveraged the proper connections to achieve its project goals.*

Reviewer 1

The reviewer remarked that the project includes strong participation from multiple states in the utility territory, multiple Clean Cities Coalitions, academic and community partner, and noted that regular communications and collaborations leveraged this wide network.

Reviewer 2

The reviewer noted that the project team includes a wide range of utility, lab, university, advocacy, and Clean Cities partners that appear to be collaborating well in executing various sub-project/task areas under the project.

The reviewer commented that it is not completely clear to what extent relevant data sharing/coordination is happening with the Regional Electric Vehicle (REV) West project and the National Association of State Energy Officials (NASEO). The reviewer added that it also is not clear to what extent the project is coordinating with or consulting with state Departments of Transportation (DOTs) on Alternative Fuel Corridor planning. Additionally, the engagement of parks/FLMAs has been a tough aspect for the project.

Question 5: *Energy Equity and Environmental Justice Project Contribution-Please provide comment on the contribution of this project to energy equity and environmental justice by ensuring the project benefits underserved and overburdened communities and does not cause increased burdens to these communities.*

Reviewer 1

The reviewer observed that the project is supporting EV training programs in underserved rural areas (i.e., Western Wyoming, and noted that the project's focus on freight electrification and EV hub placement at affordable housing locations substantively supports equity and environmental justice (EJ) goals.

Reviewer 2

The reviewer noted that multiple project activities directly and indirectly served to advance EEJ efforts; notably, workforce trainings were directly geared to these communities, while carshare and TNC efforts served underserved community members.

Presentation Number: ti129
Presentation Title: Helping America's Rural Counties Transition to Cleaner Fuels and Vehicles
Principal Investigator: Ken Brown, Transportation Energy Partners

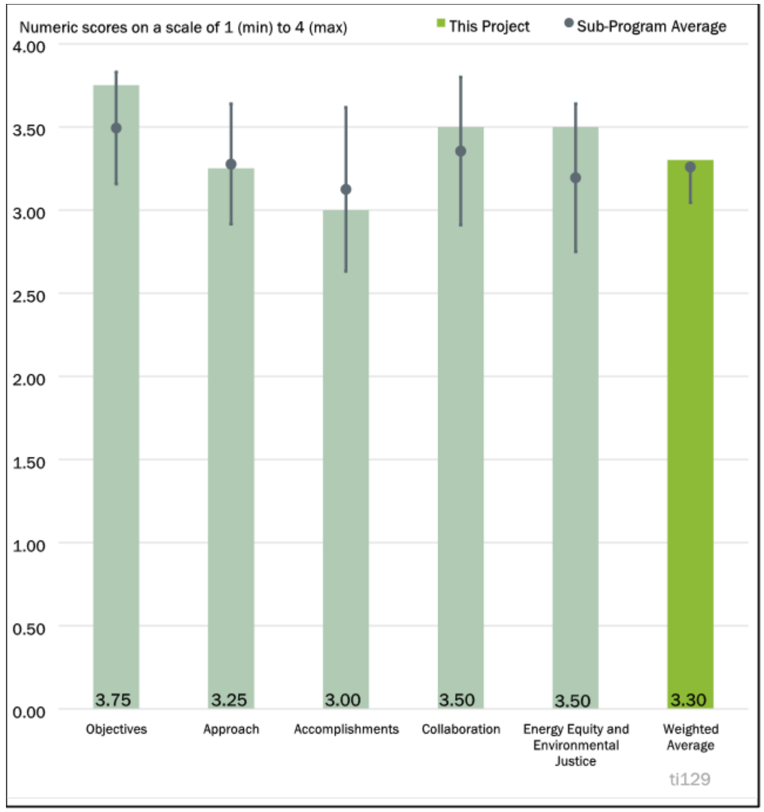

Figure 6-4 - Presentation Number: ti129 Presentation Title: Helping America's Rural Counties Transition to Cleaner Fuels and Vehicles Principal Investigator: Ken Brown, Transportation Energy Partners

Presenter

Ken Brown, Transportation Energy Partners

Reviewer Sample Size

A total of two reviewers evaluated this project.

Question 1: *Project Objectives—Please provide comments on this project's degree of support for the overall Technology Integration (TI) objectives of improving fuel diversity, increasing local resiliency, and reducing greenhouse gas emissions through increasing alternative fuel use and transportation efficiency.*

Reviewer 1

The reviewer found that this project directly supports the Technology Integration program's objective of improving fuel diversity through the use of alternative fuels, specifically in its focus on rural communities. The objective of the project is to work with rural communities to understand their challenges in implementing alternative fuel vehicles (AFVs) and then distribute a playbook of lessons learned so that successes can be replicated across the country. The reviewer remarked that this project would provide Clean Cities coalitions important information on how to work with rural communities in their areas.

Reviewer 2

The reviewer remarked that this is a truly "all of the above" approach to clean fuels, which is innovative and a strength, and that it also seems to focus almost exclusively on vehicles that are not passenger cars, which is innovative.

The reviewer opined that, the project's broad range of vehicle types (from 3 wheeled Arcimoto to heavy-duty (HD) bucket trucks and school buses,) and some of its activities feel slightly random, and noted that it is not clear what the project's key theory of change is.

Question 2: *Project Approach-Please comment on this project's approach for integrating advanced transportation technologies and practices to solve real-world challenges.*

Reviewer 1

The reviewer observed that the project approach seems to mirror the successful strategies of Clean Cities coalitions working with stakeholders to implement projects. The reviewer added that one of the key factors often cited in successful projects is having a "champion" within the organization that is deploying vehicles, and noted that the project's ultimate goal is to find local leaders that could be used as national spokespersons.

The reviewer noted that the first part of the project focused on identifying interested parties in rural communities that would want to participate in the effort. The project also obtained a range of industry partners to cover a wide variety of fuel/powertrain types, which will help with the success of the effort by allowing communities to have the options to choose what vehicles make sense for them. The reviewer observed that the project's approach involves connecting these communities with subject matter experts. In the reviewer's opinion, one challenge of this approach is that it seems the project is relying on industry partners representing specific fuels to be the experts, and project partners will need to make sure that the Clean Cities coalitions act as the neutral party to provide unbiased information.

Reviewer 2

The reviewer commented that this project identifies several barriers to clean fuels and new technologies in small and rural communities, but it is not clear that the project is well designed to address many of them. The reviewer added that it does seem likely to provide some support and help create some success stories that can be shared peer-to-peer, however. The reviewer added that more troubling is that the project does not have a clear definition of "small" or "rural", and at least some of the selected counties are not particularly rural.

Question 3: *Project Accomplishments and Progress-Please comment on the project's progress and significant accomplishments to date.*

Reviewer 1

The reviewer commented that the project seems to be fairly well on track for budget period 1, which was mostly outreach and education; however, it is much less clear whether the project will be able to deliver its ambitious program of hands-on technical assistance in eight states, and connect communities in these states with demonstration vehicles, during BP2. The reviewer expressed deep skepticism that the project can deliver that level of support and shuttle demonstration vehicles across the country within a year or so.

Reviewer 2

The reviewer commented that the major accomplishment of the project so far was being able to identify fifteen "champions" in the eight states that are part of the project. In addition, eight demonstration vehicles were contracted with project partners. The reviewer noted, however, that the project was still in negotiation about additional natural gas and propane vehicles, and it was unclear if they would be able to secure a demonstration of electric vehicles. Supply chain issues have impacted the availability of vehicles for this project, which could limit the success of the engagement with the community leaders. The reviewer noted that the project partners were able to complete the national outreach webinars, and that, while in progress, coalitions have not yet completed their stated goal of 24 outreach events with at least three performed in each state as of the presentation.

Question 4: *Collaboration and Coordination Among Project Team—Please comment on the level of collaboration within the project team and the degree to which the project team has identified and leveraged the proper connections to achieve its project goals.*

Reviewer 1

The reviewer remarked that Clean Cities coalitions have a strong history of working well together and have selected industry partners that have done significant work to support the Clean Cities mission. The reviewer noted that the presentation stated that the coalitions are having monthly calls, and quarterly all team meetings. The reviewer opined that at this early point in the project as the team is trying to identify community leaders, it seems collaboration may be less of a focus, but as the project progresses to do fleet analyses and collect lessons learned, strong collaboration and coordination will be needed.

Reviewer 2

The reviewer observed that participation by eight Clean Cities coalitions seems to be strong, and that participation of multiple fuel stakeholders on the steering committee and in the project is strong and impressive. The reviewer noted, however, that there seems to be limited participation from electric vehicle and charging stakeholders, and electric utilities, which would strengthen the project.

The reviewer commented that rural counties and communities are identified as key partners, but do not seem to be formal partners in the project, and noted that it would strengthen the project a lot if it could build partnerships and support within state and national associations of counties, cities, city managers, school districts, etc.

Question 5: *Energy Equity and Environmental Justice Project Contribution-Please provide comment on the contribution of this project to energy equity and environmental justice by ensuring the project benefits underserved and overburdened communities and does not cause increased burdens to these communities.*

Reviewer 1

The reviewer commented that rural communities are often underserved, but it is not clear that can be taken for granted. The reviewer noted that this project does not seem to have a clear and consistent understanding or approach to defining and centering underserved and overburdened communities. In other words, there is a big difference between a "rural community" on Martha's Vineyard and a rural cotton-growing community in Alabama, for example. The reviewer added that it is not clear that there are strong equity voices on the project steering committee.

The reviewer remarked that, apparently, twelve of the 24 counties being focused on have above average poverty and a couple have "above average" shares of Black and Native residents. The reviewer added that it is understandable to focus on counties that are most interested, as this project does, but that is going to select for early adopters rather than equity. The reviewer commented that benefits would be stronger if the project did more focused outreach and recruitment and DEI were a more explicit criteria in selection of the 24 counties that will receive focused support.

Reviewer 2

The reviewer remarked that this project is focused on supporting rural communities that have the resources to effectively analyze the use of alternative fuel vehicles in their area. The reviewer noted that the project includes rural areas in eight different states (with the goal of working in 24 counties), that will provide geographic variety. This variety will be beneficial as different communities have different priorities and being able to work through those issues should provide significant lessons learned for others trying to implement projects in their rural communities. The reviewer observed that the project stated that cost savings have typically been a key focus, as well as downtime, for rural communities looking at alternative fuel vehicles. This project has the opportunity to demonstrate vehicles to new communities that may provide those benefits as well as others, including lower emissions and fuel diversity.

Presentation Number: ti130
Presentation Title: VOICE-MR:Vocation Integrated Cost Estimation for Maintenance and Repair of Alternative Fuel Vehicles
Principal Investigator: Arvind Thiruvengadam, West Virginia University

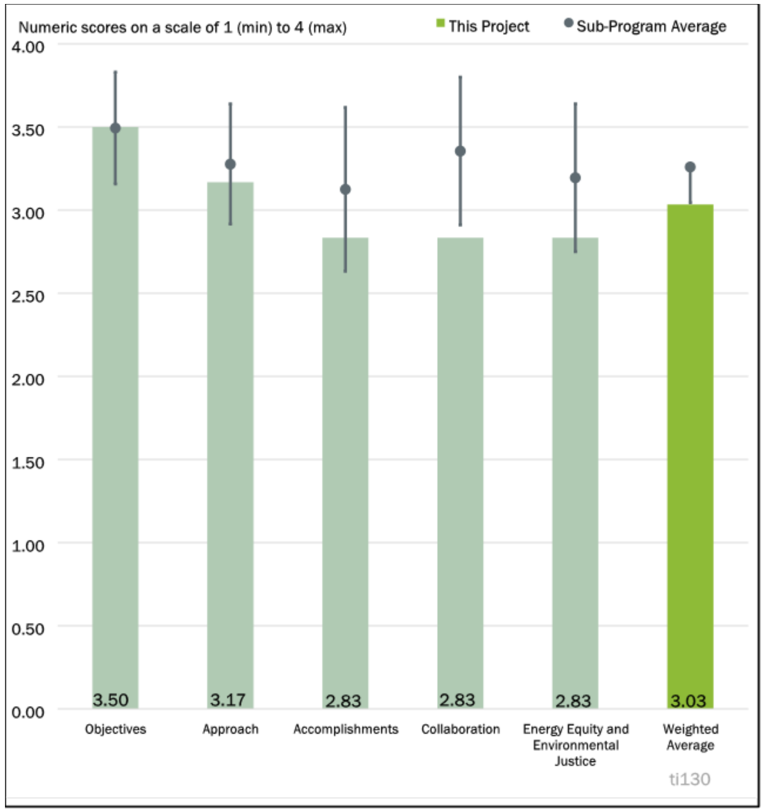

Figure 6-5 - Presentation Number: ti130 Presentation Title: VOICE-MR:Vocation Integrated Cost Estimation for Maintenance and Repair of Alternative Fuel Vehicles Principal Investigator: Arvind Thiruvengadam, West Virginia University

Presenter

Arvind Thiruvengadam, West Virginia University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: *Project Objectives—Please provide comments on this project's degree of support for the overall Technology Integration (TI) objectives of improving fuel diversity, increasing local resiliency, and reducing greenhouse gas emissions through increasing alternative fuel use and transportation efficiency.*

Reviewer 1

The reviewer commented that this effort addresses a key data gap that is missing when performing cost of ownership analysis of heavy-duty alternative fuel vehicles versus their diesel counterparts by examining the potential maintenance savings that AFVs may provide based on fuel type, vocation, and geographic region. The reviewer added that public maintenance data is very limited for both diesel with new aftertreatment technologies (selected catalytic reduction and particulate filters) and AFVs. If the data shows that there are clear maintenance savings for certain AFVs that would help in the deployment of these technologies, which would improve fuel diversity and potentially improving resiliency. Further, this may also lead to GHG benefits, but not necessarily, as fossil natural gas and propane vehicles may not provide much, if any, benefits, even though they have lower maintenance costs.

Reviewer 2

The reviewer stated that this effort is very important to overcoming fleet resistance to using alternative fuel vehicles that support the TI objectives highlighted above. The resistance addressed relates to uncertainty regarding operational costs and potential savings related to maintenance so this project's focus on identifying better data and using artificial intelligence to project similar costs and benefits for other applications is good use of DOE funding.

Reviewer 3

The reviewer remarked that this project is directly addressing identified barriers for fleets to transition to AFVs and, importantly, is delineating data by vocation, duty-cycle and regional temperature variations which will make the end result more precise and thus more informative to fleets.

Question 2: *Project Approach-Please comment on this project's approach for integrating advanced transportation technologies and practices to solve real-world challenges.*

Reviewer 1

The reviewer remarked that the key to success of this project is being able to collect significant amounts of maintenance and repair data from a variety of fleets/vehicles efficiently. The project benefits from being able to leverage data collection from one of its partners projects (South Coast Air Quality Management District [SCAQMD]) to the right. The challenge of this type of effort is that while it is beneficial to collect as much data as possible from a wide variety of fleets, this can lead to significant data cleaning efforts by the project team due to the variability in record-keeping of different fleets. The reviewer noted that the presenter mentioned that they have been scanning paper records to put into a database, which is a laborious process. Still, it is necessary to have a good relationship with the fleets to be able to do their fleet interviews and follow-up on the data. The project task to create a web interface for data gathering is a good idea if it allows fleets to submit data easily.

The reviewer noted two other major components of the project and issues related to them: One was the project's effort to tie maintenance cost data to the vehicle's duty cycle through the use of telemetry data and other factors such as ambient temperatures and vehicle age. This is an important factor to understand as anecdotal discussions of maintenance of diesel vehicles with the most recent aftertreatment technologies have suggested that low speed and low load conditions were problematic. Therefore, it is necessary to differentiate duty cycles when doing comparisons with alternative fuel vehicles. A second factor cited by the reviewer was creating a machine learning model to estimate maintenance costs based on duty cycle. From the presentation, the machine learning aspects of the project are not necessarily clear on how they will be implemented and how the project team will mitigate biases in training this model.

Reviewer 2

The reviewer remarked that this may not directly involve integrating technology but rather is about understanding the advantages of different advanced technologies by reviewing and assessing data on maintenance and costs. The reviewer added that the technology integration could be the development of the artificial intelligence used in this project.

Reviewer 3

The reviewer indicated that there is so much variety in the medium and heavy duty vehicle space and this is a difficult task to tackle, but this project is a good starting point. The sample size and vocation list is a good start, but may not reach a statistically significant threshold to draw accurate conclusions for all vocations and regions of the country. The reviewer pointed out that the vocation list in particular is quite limited compared to the Engine Manufacturers Association's (EMA)'s list of 90+ vocations and is missing some key applications such as regional haul, transit, etc.

Question 3: *Project Accomplishments and Progress-Please comment on the project's progress and significant accomplishments to date.*

Reviewer 1

The reviewer commented that it sounds like there have been some delays that are not surprising; however, it would be useful to make sure alternative fuel data increases to better match diesel data.

Reviewer 2

The reviewer noted that the project seems to be largely on track after a delayed start, and that it would be helpful to see more fleets committing to contributing data, especially fleets in the middle of the country, along with a greater diversity of vocational types.

Reviewer 3

The reviewer noted that the project looks to be behind schedule, and the presenter mentioned that the pandemic had led to challenges in collecting fleet data. In addition, delays in sub award agreements with Clean Cities coalitions have slowed participation as well. It was mentioned when the presentation was developed that 200 vehicles were providing data (100 coming from a SCAQMD project), and that by the time the presentation was done they were up to 350. The presentation showed that 17 fleet types were identified for agreements to share data, while 7 fleets were sharing data at the time of the presentation being developed. The reviewer commented that it was not clear from the presentation what the project's goal was for data collection for each vehicle vocation, so it is difficult to gauge how close they are to meeting their own expectations at the beginning of the project.

The reviewer added that as the project is only focusing on production vehicles, it is understandable that they have so few electric vehicles; however, they are missing a key vocation in transit buses to collect EV as well as other alternative fuel powertrain maintenance cost data. The reviewer strongly recommended that they collect this data even in cases where they may not have a diesel counterpart to compare to, and noted that this seems to be the plan for some of their propane vehicles. Collecting transit bus data would likely provide some hybrid diesel data as well. The reviewer noted that there is a significant percentage of propane vehicles being collected so far, which is understandable since the Propane Education and Research Council (PERC) is one of the project partners; however, it would be beneficial to focus efforts on collecting additional natural gas vehicle data.

Question 4: *Collaboration and Coordination Among Project Team—Please comment on the level of collaboration within the project team and the degree to which the project team has identified and leveraged the proper connections to achieve its project goals.*

Reviewer 1

The reviewer remarked that it looks like a great team has been put together, as well as processes to collect and review data.

Reviewer 2

The reviewer noted that the project team is quite small and academically focused, and the addition of Clean Cities partners, fleets and industry groups from other regions of the country, and other AFV types, would be beneficial to ensure the final product is useful to fleets as a decision making tool.

Reviewer 3

The reviewer noted that Clean Cities coordinators have helped with initial conversations to introduce fleets to West Virginia University (WVU); however, delays in sub award agreements with Clean Cities coalitions have slowed participation. The reviewer commented on the presenter's statement that funding partners help target which fleets to go after, saying that the process was not explained very well. The reviewer added that it seems the team needs further coordination to make sure that a wide range of fleets in different vocations throughout the country are being engaged.

Question 5: Energy Equity and Environmental Justice Project Contribution-Please provide comment on the contribution of this project to energy equity and environmental justice by ensuring the project benefits underserved and overburdened communities and does not cause increased burdens to these communities.

Reviewer 1

The reviewer indicated that it is difficult to grade this project on equity and environmental justice, as the focus is on collecting data to support fleet decision-making, but added that ultimately, the data from this project can lead to increased AFV adoption, which may ultimately provide emissions benefits to communities in both rural and underserved areas. The reviewer noted that the project is trying to get data in rural regions and help fleets in those areas to understand their experience, although it is not clear how successful they have been so far at this.

Reviewer 2

The reviewer stated that this type of project is a precursor to future deployment that will provide benefits sought here, i.e., equity and environmental justice, so this is important. The reviewer added that this work will not directly influence those objectives but will be useful to future projects directed at serving those objectives.

Reviewer 3

The reviewer observed that the presenter did not address impacts to underserved and overburdened communities in slides or in the presentation. The reviewer surmised that increased use of alternative fuel vehicles will positively impact air quality and potentially lower transportation and health costs in these communities, but stated that it was not directly noted in the presentation.

Presentation Number: ti131
Presentation Title: DRIVE (Developing Replicable, Innovative Variants for Engagement) for Electric Vehicles (Evs) in the USA
Principal Investigator: Jonathan Overly, East Tennessee Clean Fuels Coalition

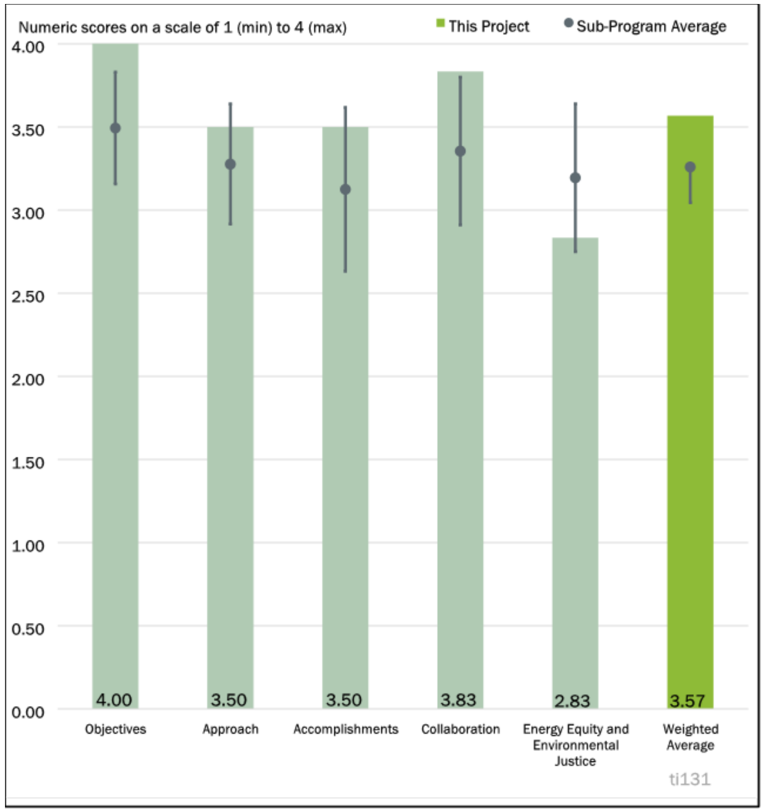

Figure 6-6 - Presentation Number: ti131 Presentation Title: DRIVE (Developing Replicable, Innovative Variants for Engagement) for Electric Vehicles (Evs) in the USA Principal Investigator: Jonathan Overly, East Tennessee Clean Fuels Coalition

Presenter

Jonathan Overly, East Tennessee Clean Fuels Coalition

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: *Project Objectives—Please provide comments on this project's degree of support for the overall Technology Integration (TI) objectives of improving fuel diversity, increasing local resiliency, and reducing greenhouse gas emissions through increasing alternative fuel use and transportation efficiency.*

Reviewer 1

The reviewer remarked that the project is focused on creating 14 replicable, statewide programs that are thriving in creating partnerships in each state, to greatly accelerate EV adoption across LD, MD and HD vehicle types. The reviewer praised this project as being strongly responsive and aligned with VTO/TI objectives.

Reviewer 2

The reviewer commented that this project is tackling education and outreach in a big way across a broad coalition of stakeholders, and applauded it for having a good mix of grassroots engagement paired with an overarching objective, and for being built in a way that is intended to be easily replicated.

Reviewer 3

The reviewer commended the project for its strong multistate team, and for leveraging many different activities including a statewide, branded program; consumer education; utility and regulator engagement; EV charging infrastructure and planning; education of state and local government officials; dealer engagement; and fleet engagement and EV adoption. The reviewer found this to be an admiral set of objectives, but posited that it remains to be seen if the project will be more effective in some issue areas than in others.

Question 2: *Project Approach-Please comment on this project's approach for integrating advanced transportation technologies and practices to solve real-world challenges.*

Reviewer 1

The reviewer remarked that the project approach is very focused on building a replicable EV education and outreach program, and noted that it has seven priority areas, with project objectives and milestones that are well aligned with those priorities.

Reviewer 2

The reviewer commented that the DRIVE USA project is bringing many different activities together, with priority areas that include consumer education, utility engagement, dealer engagement, and charging infrastructure planning.

Reviewer 3

The reviewer commented that the project comprehensively assesses each state's EV readiness, and noted that local dealer engagement and targeted general management at each local dealer to address staff turnover is a key part of the project's strategy/approach.

The reviewer observed that the project is collecting a lot of information on activities and programs within each participating state, but noted that it was not clear from the presentation to what extent, if any, the project is providing valuable state data to the Alternative Fuels Data Center (AFDC), and stated that this could be a missed opportunity.

Question 3: *Project Accomplishments and Progress-Please comment on the project's progress and significant accomplishments to date.*

Reviewer 1

The reviewer observed that the project has completed all budget period one activities on schedule and has also completed many of the budget period two activities, and noted that they are also well ahead of their stated goals for media engagements, media impressions and direct engagements, including two high profile events with state governors.

Reviewer 2

The reviewer commented that collaboration leading to the creation or strengthening of 14 statewide programs will be a solid impact, and noted that the group seems to have a done a good job of establishing the process and connections to make that happen. The reviewer also commented that they are recording significant outreach impacts from digital engagements and impressions, as well as in person outreach, and that these numbers will exceed the original goals.

Reviewer 3

The reviewer remarked that the project has started (from ground up) new EV initiatives in nine states, and has furthered existing EV initiatives in five states.

The reviewer commented that the project's budget seems underspent, and noted that neither this nor a plan to catch up on progress was explained during the presentation.

Question 4: *Collaboration and Coordination Among Project Team—Please comment on the level of collaboration within the project team and the degree to which the project team has identified and leveraged the proper connections to achieve its project goals.*

Reviewer 1

The reviewer commented that the well-represented Project Advisory Committee (PAC,) consisting of 53 individuals from 34 different key organizations, such as Plug In America, NASEO, National Rural Elec. Coop. Assn., CALSTART, etc., is an excellent feature of the project. The reviewer added that the project involves an impressive statewide partner mix within each participating state.

Reviewer 2

The reviewer expressed appreciation for the project leadership team's approach to bringing this particular collection of states together, and stated that the involvement of 14 states that are in the middle of the pack on EV adoption is very helpful in tackling the EV adoption challenges being experienced by the average citizen, fleet manager, government leader, etc. The reviewer noted that the team seems to be collaborating effectively and even attracting new partnerships in the process.

Reviewer 3

The reviewer noted strong collaboration among 14 different Clean Cities Coalitions, and a PAC that has 34 additional organizations participating. The reviewer commented that with various subcommittee meetings, the level of participation and engagement seems very high.

Question 5: *Energy Equity and Environmental Justice Project Contribution-Please provide comment on the contribution of this project to energy equity and environmental justice by ensuring the project benefits underserved and overburdened communities and does not cause increased burdens to these communities.*

Reviewer 1

The reviewer remarked that the project has been committed to inclusive statewide partnerships since the beginning and is incorporating additional communities that are of interest to DOE.

Reviewer 2

The reviewer commented that there are many indirect equity and EJ benefits from the project, although this is not a main focus of the scope.

Reviewer 3

The reviewer stated that, overall, this seems like a strong project with statewide engagement, including states that have not yet had strong EV programs. The reviewer observed that although EEJ had not been a core focus, the project sought strong rural outreach, and is supporting Clean Cities coalitions that are looking to ensure equity considers are included as part of their core operations.

**Presentation Number: ti132
Presentation Title: The National Fire Protection-Association (NFPA) Spurs the Safe Adoption of Electric Vehicles through Education and Outreach
Principal Investigator: Andrew Klock, National Fire Protection Association**

Presenter

Michael Gorin, National Fire Protection Association

Reviewer Sample Size

A total of four reviewers evaluated this project.

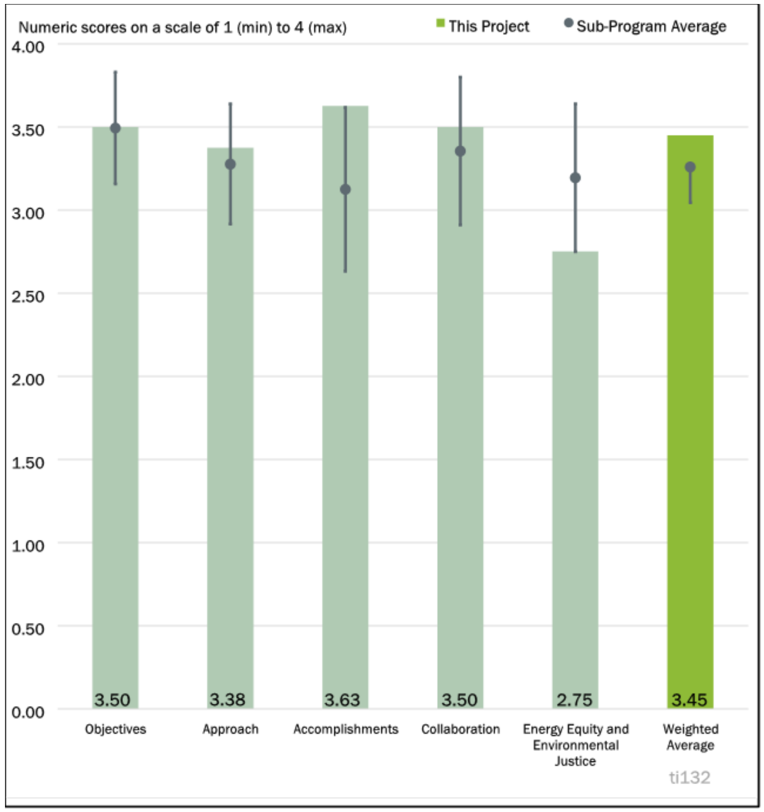

Figure 6-7 - Presentation Number: ti132 Presentation Title: The National Fire Protection-Association (NFPA) Spurs the Safe Adoption of Electric Vehicles through Education and Outreach Principal Investigator: Andrew Klock, National Fire Protection Association

Question 1: *Project Objectives—Please provide comments on this project's degree of support for the overall Technology Integration (TI) objectives of improving fuel diversity, increasing local resiliency, and reducing greenhouse gas emissions through increasing alternative fuel use and transportation efficiency.*

Reviewer 1

The reviewer commented that the project was created to directly support Technology Integration objectives with regard to the adoption of electric transportation, and noted that education and training are key to adoption of an alternative fuel (electricity). The reviewer added that the project targets the public and particularly those directly involved with code enforcement and safety, and thoughtfully includes dealerships and insurance adjusters.

Reviewer 2

The reviewer remarked that the project is focused on increasing EV knowledge and enabling better community planning and preparedness that supports mass EV adoption, and noted that they are doing this through development of web-based learning and workshops with specific target audiences in mind.

Reviewer 3

The reviewer stated that the project supports the overall TI objectives, especially, increasing local resiliency, by providing local training on EV Community Preparedness.

Reviewer 4

The reviewer commented that this project actively increases local resiliency; however, it does not improve fuel diversity or reduce GHG emissions.

Question 2: *Project Approach-Please comment on this project's approach for integrating advanced transportation technologies and practices to solve real-world challenges.*

Reviewer 1

The reviewer remarked that the project team has significant experience in providing training programs and has outlined an effective project approach, including development of multiple formats for training and segmented training modules based on the needs of specific audiences. The reviewer found the inclusion of many different audiences in the training curriculum to be particularly notable, and noted that beyond just first responders, there are also courses specific to insurance adjusters, crash reconstruction specialists, utilities, etc.

Reviewer 2

The reviewer commented that the project's approach was excellent, and noted that the workshops are being designed for both virtual and in-person attendance, which increases the potential for wider participation.

Reviewer 3

The reviewer remarked that the project supports integration of technologies, as it addresses education, the first step needed for individuals and fleets to consider integration of advanced technologies. The reviewer noted that lack of basic (and targeted) knowledge of EVs is a real world challenge to all who use transportation, and stated that the resulting online training and workshops offer an easy way to find the facts, benefits and pitfalls of the technology.

Reviewer 4

The reviewer applauded the project and the development phase of the modules, but saw room for improvement in the rollout process. The reviewer recommended that 40% of these workshops be held in disadvantaged communities and that at least one should be held in each state, and stated that there could be more marketing around the workshops and the online modules.

Question 3: *Project Accomplishments and Progress-Please comment on the project's progress and significant accomplishments to date.*

Reviewer 1

The reviewer observed that all budget period one milestones are completed and some from budget period two, and that the online training components have been fully implemented and some pilot workshops have been conducted. The reviewer complimented the project website as being highly polished and professional.

Reviewer 2

The reviewer commented that the project is on track and many achievements have been made. The reviewer was very impressed with the online modules.

Reviewer 3

The reviewer commented that the project is on target, all courses are complete, and Clean Cities coalitions are currently conducting Community Preparedness Assessment workshops.

Reviewer 4

The reviewer stated that the project has completed all the material for conducting workshops, and the only remaining major milestones are delivering the workshops.

Question 4: *Collaboration and Coordination Among Project Team—Please comment on the level of collaboration within the project team and the degree to which the project team has identified and leveraged the proper connections to achieve its project goals.*

Reviewer 1

The reviewer commented that the Principal Investigator was very informed and the team seems to work smoothly together.

Reviewer 2

The reviewer noted that the project team has a diverse advisory group and has also assembled a large list of workshop hosts.

Reviewer 3

The reviewer stated that the project team was very small, but exhibited good collaboration and coordination.

Reviewer 4

The reviewer commented that the project lead and partners are doing an excellent job with incentivizing clean cities coalitions to run these workshops, and noted the presenter's statement that the website has been made available at no cost, which guarantees the online courses will be available after the project end date. The reviewer indicated that the workshops have value beyond the project end date that hopefully will continue beyond 2023. The reviewer added that as we learn more about adoption and community preparedness assessing, these tools will need to be updated, but noted that the presenter did not indicate if there is a plan for revision of these courses as policy and best practices change, and as newer models of charging and vehicles become available.

Question 5: *Energy Equity and Environmental Justice Project Contribution-Please provide comment on the contribution of this project to energy equity and environmental justice by ensuring the project benefits underserved and overburdened communities and does not cause increased burdens to these communities.*

Reviewer 1

The reviewer commented that the project partners are interested in making their event accessible to everyone through virtual delivery options, and have identified both large and small communities to target for workshops. Marketing materials are targeted to audiences beyond the "usual suspects".

Reviewer 2

The reviewer remarked that the project workshops and resources will support all communities; they are not specifically targeted toward underserved and overburdened communities.

Reviewer 3

The reviewer commented that the project can be a contributor to EEJ in the long term, and saw the benefit to the underserved as the result of the education received by communities.

Reviewer 4

The reviewer observed that, when asked about equity, the PI could really only point to the fact that these courses are free and available to everyone. The reviewer expressed the view that this is not enough, and that underserved and overburdened communities should be marketed to, to ensure the awareness of the tool, and that workshops should be held in these communities.

Presentation Number: ti134
Presentation Title: Delivering Clean Air in Denver: Propane Truck and Infrastructure in Mail Delivery Application
Principal Investigator: Bonnie Trowbridge, Drive Clean Colorado

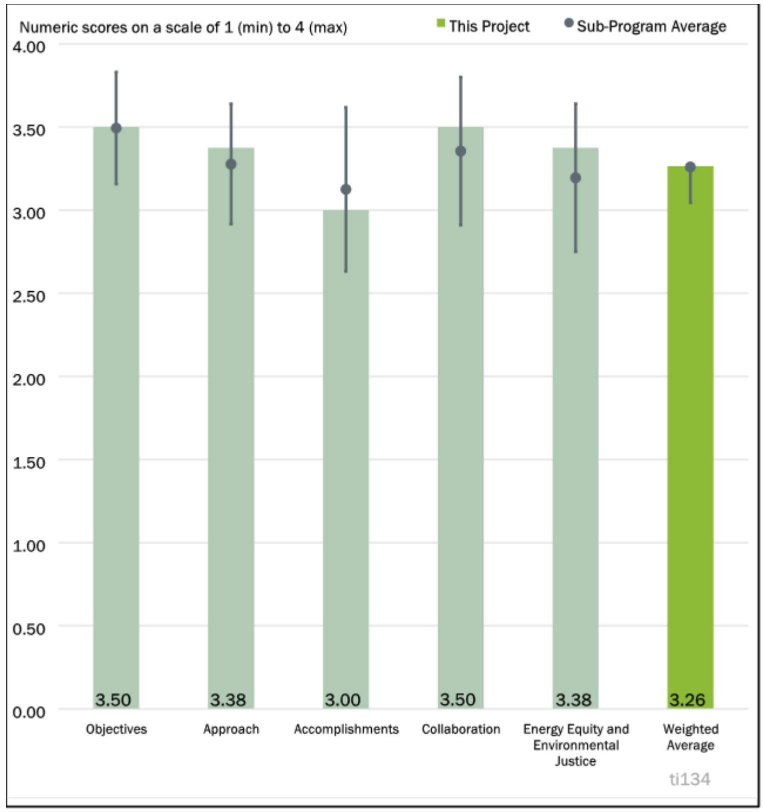

Figure 6-8 - Presentation Number: ti134 Presentation Title: Delivering Clean Air in Denver: Propane Truck and Infrastructure in Mail Delivery Application Principal Investigator: Bonnie Trowbridge, Drive Clean Colorado

Presenter

Bonnie Trowbridge, Drive Clean Colorado

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: *Project Objectives—Please provide comments on this project's degree of support for the overall Technology Integration (TI) objectives of improving fuel diversity, increasing local resiliency, and reducing greenhouse gas emissions through increasing alternative fuel use and transportation efficiency.*

Reviewer 1

The reviewer commented that deploying alternative fuel vehicles in higher mileage applications provides an excellent opportunity to displace petroleum and reduce GHG emissions, and the more that can be learned about duty cycles and operational needs of specific applications like this (regional mail delivery), the greater the likelihood others will undertake similar projects.

Reviewer 2

The reviewer observed that the project is clearly focused on using alternative fuel (liquified petroleum gas, [LPG]) in a specific application (U.S. Postal delivery from depots to local post offices). The reviewer stated that there has been a lack of understanding of how this fuel could be applied to this application, which provides the opportunity to see significant per-vehicle fuel cost savings. The reviewer noted that the trucks operate 100 to 200 miles per day, and added that the idea is to help other fleets with similar types of trucks transition their fleets. The reviewer also noted that significant outreach and education are included as part of the project.

Reviewer 3

The reviewer commented that the project objectives are clear, i.e., to demonstrate the impact of a propane-powered fleet, by conducting real-world data collection and analysis on a United States Postal Service (USPS) fleet near Denver, Colorado.

Reviewer 4

The reviewer observed that propane is important in transportation fuel diversification and although this project involves a small number of trucks to be owned by one company (Hi Pro), the company is a nationwide contractor for the USPS, so there is the potential for propane trucks to be a significant part of their large fleet. The reviewer referenced the presenter indicating that Hi Pro is discussing transitioning its entire fleet to propane.

The reviewer stated that transporting mail consumes a huge amount of resources, significantly contributing to air pollution. The reviewer observed that the USPS is enthusiastic about the cleaner fuel, and that Drive Clean Colorado is helping Hi Pro through the process, and added that it was fortunate that Hi Pro could secure a longer, more secure contract from USPS.

The reviewer expressed the opinion that it was disturbing to hear that the State of Colorado appears to be leaning toward electrification of fleets rather than being open to other options that might be as good or better depending on the MD/HD applications.

Question 2: *Project Approach-Please comment on this project's approach for integrating advanced transportation technologies and practices to solve real-world challenges.*

Reviewer 1

The reviewer commented that collecting data on actual vehicles in actual service is critical to understanding real-world benefits, so this is very useful.

Reviewer 2

The reviewer observed that the project focused on putting five LPG box trucks into a fleet application and evaluating performance, particularly for relatively high-fuel use vehicles, and noted that the project partners are also working closely with the manufacturer (Roush) to help them improve their product.

The reviewer commented that the data collection plan is for 10 days of operation in the summer and 10 days in the winter, and while they seem to have a plan to collect useful information, that is probably a little light as far as duration; ideally a month in each season would be a bit better. The reviewer added that a longer duration would help to eliminate the impacts of possible unique or one-time events on operation.

Reviewer 3

The reviewer stated that the approach is clear and the PI will be collecting data on both the fleet operations and the propone fueling infrastructure, and added that the outreach component in budget period three will be very important.

Reviewer 4

The reviewer commented that transportation of mail is a constant and as an independent agency operated by the federal government and subject to pressure to reduce harmful vehicle emissions, USPS needs to diversify its fleet to include cleaner fuels/better technology. The reviewer stated that this project directly addresses the challenge by providing a large contractor an opportunity to see how propane works in the mail delivery system.

The reviewer observed that a more recent real-world challenge has been dealing with shortages of workers and materials needed to manufacture, upfit and convert these vehicles within the time frame of the project, and added that the price increase (partially due to these factors) is a hard sell to a company that is new to the technology and a bit nervous. The reviewer noted that a mistake that brought the trucks to the wrong address and a second mistake of installing the wrong box on the chassis adds to the partners' frustrations. The reviewer commented that it is commendable that the PI was able to work through these issues with minimal fallout, and added that double and triple checking details at every step, with representatives from the manufacturer, upfitter and all other liaisons may be necessary going forward and may reduce these errors.

The reviewer noted that data will be collected over a ten-day period, and that this information prompted questions about the types of data to be collected. The reviewer expressed the view that ten days is a short period of time, there are many factors involved (weather, temps, driver), and that a longer span of time for data collection could yield more reliable information.

Question 3: *Project Accomplishments and Progress-Please comment on the project's progress and significant accomplishments to date.*

Reviewer 1

The reviewer commented that, given the current environment and supply chain delays, it is understandable this project has encountered some delays, and added that there might be some good lessons learned that could be shared with others, as these issues could persist for some time.

Reviewer 2

The reviewer noted that delivery of the trucks has been delayed but is scheduled for this week or next, and that the control (diesel) vehicles have already been instrumented. The reviewer observed that LPG trucks and infrastructure were expected to be in operation by the end of 2021, but the schedule got shifted to mid-2022. (They were ordered as expected in March 2021, but supply chain issues were significant.) The reviewer commented that during the delay, Ford increased the price of the trucks by $7500, which was not budgeted in the project, but the project team worked with the operating fleets and kept them on board. The reviewer observed that the fleets' contracts with USPS were being renegotiated, but USPS was willing to pay more since they needed the service. In addition, Ford incorrectly shipped the trucks to the box installer first, rather than to the LPG installer (Roush). The reviewer observed that this caused additional problems, but the project team has stepped in to keep things on track. The reviewer added that they saw similar delays for the refueling system, particularly with permitting, due to staffing issues, but the station is now permitted and active on the site and should see initial operation very soon.

Reviewer 3

The reviewer observed that the project is a bit behind; however, the PI's ability to keep the project together given all the setbacks with the manufacturer, change in price, and upfit mistake is commendable, and it is hoped that the vehicles arrive and be in operation soon. The presenter mentioned that the infrastructure has been installed but not yet used. The reviewer expressed the view that it would be helpful if it could fuel a vehicle prior to the arrival of the pilot vehicles to be certain it's in working order, and suggested that all project partners keep tabs on price and purchasing options of propane.

Reviewer 4

The reviewer stated that the project has undergone a number of delays and price increases related to supply chain issues; however, they were able to collect baseline data and the trucks were to be delivered at the time of the Annual Merit Review (AMR) (June 2022).

Question 4: *Collaboration and Coordination Among Project Team—Please comment on the level of collaboration within the project team and the degree to which the project team has identified and leveraged the proper connections to achieve its project goals.*

Reviewer 1

The reviewer observed that the project team has been working closely with the fleets, manufacturer, dealer, station installer, and local officials, and added that the project team has had to spend a lot of time working through the relationships due to the project delays. In particular, the principal investigator mentioned working with the station installer early. The reviewer stated that, overall, these are the types of organizations required for this kind of project and the project team has worked hard to maintain the necessary relationships under less-than-perfect conditions. The reviewer added that they are to be commended on that.

Reviewer 2

The reviewer observed that Drive Clean Colorado has a strong group of partners that meet regularly for updates and discussion, and stated that the PI's patient and skillful handling of the myriad of problems that have occurred during this project has strengthened relationships in the supply chain and with partners. The reviewer added that the PI's diplomacy, Hi Pro's patience with regards to barriers to the smooth delivery and deployment of vehicles, and USPS's enthusiasm for a contracted company to use propane in its vehicles has kept this project afloat and headed forward.

Reviewer 3

The reviewer commented that there is a strong team in place.

Reviewer 4

The reviewer stated that the team requires coordination with the fleet owner, the National Renewable Energy Laboratory (NREL), and the propane company, and the coordination appears to be going well.

Question 5: *Energy Equity and Environmental Justice Project Contribution-Please provide comment on the contribution of this project to energy equity and environmental justice by ensuring the project benefits underserved and overburdened communities and does not cause increased burdens to these communities.*

Reviewer 1

The reviewer observed that the trucks will reduce emissions in one of dirtiest zip codes in the country; therefore, removing diesel at this location is critical, and this project can show a pathway to much lower emissions in an area with high asthma rates, etc. The reviewer added that the fleet owner has indicated they would like to convert their entire fleet to LPG and be a hub for other nearby fleets.

Reviewer 2

The reviewer remarked that the vehicles will be operating in one of the dirtiest areas in the country, home to an oil refinery and major highway exchanges, so this project has the potential to significantly benefit overburdened communities by way of cleaner air and reduced particulate matter. The reviewer noted that this pilot is designed to be replicated, and the expansion of Hi Pro's propane fleet from gas and diesel to cleaner propane will likely have far reaching benefits in the mail services industry.

Reviewer 3

The reviewer commented that this project supports the goal of energy equity and environmental justice as these trucks will be based in an urban setting with very poor air quality, so the emission reductions should benefit communities disproportionately impacted by poor air quality and exposed to vehicle pollution.

Reviewer 4

The reviewer commented that the project goal of reducing harmful vehicle emissions in the Denver area will improve air quality, and poor air quality has a bigger impact on underserved and overburdened communities.

Presentation Number: ti135
Presentation Title: Advancing Climate & Innovation Goals of Memphis & Shelby County: Electrification of Key Fleet Vehicles to Capture Cost Savings and Climate Benefits
Principal Investigator: Leigh Huffman, Shelby County

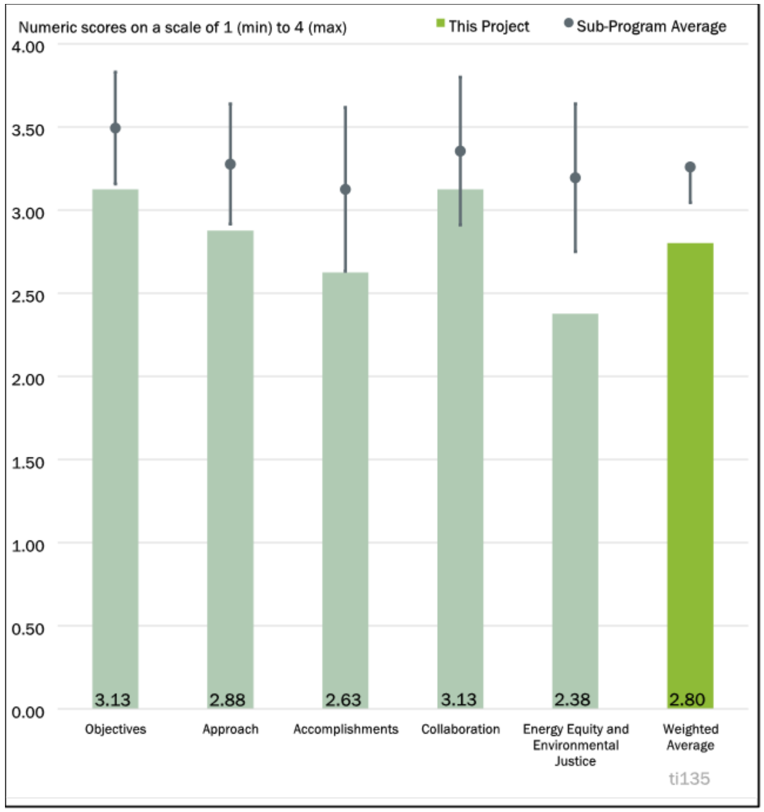

Figure 6-9 - Presentation Number: ti135 Presentation Title: Advancing Climate & Innovation Goals of Memphis & Shelby County: Electrification of Key Fleet Vehicles to Capture Cost Savings and Climate Benefits Principal Investigator: Leigh Huffman, Shelby County

Presenter

Leigh Huffman, Shelby County

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: *Project Objectives—Please provide comments on this project's degree of support for the overall Technology Integration (TI) objectives of improving fuel diversity, increasing local resiliency, and reducing greenhouse gas emissions through increasing alternative fuel use and transportation efficiency.*

Reviewer 1

The reviewer stated that the project supports fuel diversity and resiliency for this government. This will be Shelby County's first procurement of fully electric vehicles and more EVs are likely to be added to the County's fleet if this pilot is successful.

The reviewer observed that the project changed from the original plan, which was to purchase four F250s converted to plug-in hybrid-electric vehicles (PHEVs), but the current plan is to purchase "2-3 Mustang Mach-Es" and "1-2 Ford Lightnings." Because the project is procuring EVs and not PHEVs, the reviewer gave an "excellent" rating on project objectives.

The reviewer noted that the Mach-Es will be inspection vehicles for the Roads, Bridges and Engineering Department which, when delivered, should bring positive feedback from drivers; it's not your typical county-owned inspector's vehicle.

Reviewer 2

The reviewer commented that the project is good as a very first project of alternative fueled vehicles with a fleet that has not had previous experience, and noted that it will certainly provide exposure and experience to a fleet with electric vehicles even if with a very small number of vehicles (five total) plus infrastructure.

Reviewer 3

The reviewer remarked that the project is focused on addressing the lack of EVs in the county's fleet, but there is very little familiarity with EV technologies and little data to support decision-making. The reviewer noted that the idea is to do the homework to allow for expansion to much of the rest of the county's fleet and ideally serve as an example to others in the area.

Reviewer 4

The reviewer commented that this project improves fuel diversity and increases local resiliency; however, since these vehicles are new vehicles and will not be replacing current fleet vehicles, the project does not reduce GHG emissions and actually increases GHG emissions if the original fleet use continues at a business as usual rate.

Question 2: *Project Approach-Please comment on this project's approach for integrating advanced transportation technologies and practices to solve real-world challenges.*

Reviewer 1

The reviewer commented that the approach is direct and simple: order vehicles, install charging, receive vehicles, train staff, collect data and share the positive impact while educating the community (good PR).

Reviewer 2

The reviewer stated that the approach is to deploy five EVs into the county fleet—four light-duty vehicles (LDVs) and one MD truck (Class 6 Lion), and noted that they are also installing EVSE and training operations and maintenance staff. The reviewer noted that they did have to adjust their approach on vehicle types significantly, as the original plan was for F-250s converted by XLFleet, but an evaluation showed that the supplier's (XL's) product probably would not work for the planned application. The reviewer stated that for the MD truck, the original supplier also indicated they could not get a vehicle to convert for 18 months, so the project team had to shift to Lion.

The reviewer commented that the approach does sound a bit light on plans for outreach both within the county government and outside; however, to be fair, the principal investigator came into the project only last fall, so the plan for outreach would likely be expected to evolve a bit over time.

Reviewer 3

The reviewer expressed approval that the fleet targeted for this pilot was the largest city fleet and was tied into current division goals, and appreciated the flexibility in approach of the project as it ran into road blocks and barriers. The reviewer commented that it would be better to use the new electric vehicles as replacement vehicles and expressed a desire to see more equity considerations.

Reviewer 4

The reviewer remarked that the fleet will get some valuable experience from integrating charging infrastructure and EVs. The reviewer added that engaging the fleet(s) as a willing partner in the proposal phase and understanding their needs and routes ahead of time would be recommended.

Question 3: *Project Accomplishments and Progress-Please comment on the project's progress and significant accomplishments to date.*

Reviewer 1

The reviewer remarked that project progress is as far as allowed by the supply chain delays.

Reviewer 2

The reviewer observed that the project is significantly behind due to procurement delays, so the team received the ability to move budget period one (budget period 1) funds into budget period 2. The reviewer noted the following progress: they are working on installing the EVSE as part of an overall Engineering facility upgrade;

the renovation design kicked off yesterday and EVSE will be a priority; they have decided on their EVSE location and equipment; they held several EV demonstrations for county staff so they could see if the vehicles could meet their needs, particularly for meeting fleet needs with EVs other than pickups in some cases; they issued the purchase orders for the first EV (Ford Mach-E). The reviewer noted that the reworked plan is now to get 2-3 Mach-Es and 1-2 F-150 Lightnings, a data collection plan has been developed, and efforts have begun to collect data on control vehicles.

The reviewer commented that while they have not accomplished a great deal compared to their original plan, a lot of the delays were out of their control, such as COVID-19 and related supply chain issues.

Reviewer 3

The reviewer noted that there have been delays and problems, the most concerning being staff turnover, i.e., the change (twice) in project administrators. The reviewer added that supply chain issues are plaguing all who have procurement projects with strict end dates.

The reviewer gave the project a fair rating, but commented that this should not be a reflection of the work of the current administrator, as many of the glitches with this project were out of her control, and it takes time to get up to speed in a project, particularly one with vehicle procurement issues/delays.

The reviewer stated that the PI has kept the project moving, although completion is only 34% halfway through the project period with less than $35,000 spent to date on a project with a $1million budget. The reviewer added that the project is moving forward and it is expected that money will be quickly expended once the vehicles arrive. The reviewer found it disconcerting that charging stations have yet to be installed, but discussions with team partners may generate ideas that can move that along more quickly.

Reviewer 4

The reviewer noted that the project was slow to start and had some challenges with change in project lead and supply chain issues. The reviewer added that the charging location has been selected, EV demonstrations were held, and key data points in the data collection plan were identified; however, the acquisition of the vehicles has been slow. The reviewer commented that the data collection plan elements could have been included in the slides, as well as information on who will be collecting the data.

The reviewer recommended that, in addition to the return on investment (ROI) for vehicles and charging stations, the PI conduct surveys with the user fleet and gather input on satisfaction and what could be improved.

Question 4: *Collaboration and Coordination Among Project Team—Please comment on the level of collaboration within the project team and the degree to which the project team has identified and leveraged the proper connections to achieve its project goals.*

Reviewer 1

The reviewer complimented the project on the wide net of project partners and the coordination among the teams.

Reviewer 2

The reviewer noted that partners include the county fleet; county roads/bridges/engineering; the Clean Cities coalition; the utility; Ford; and Lion, and added that they have been working closely with all team members, particularly through the delay process.

Reviewer 3

The reviewer stated that choosing to procure fully electric vehicles better promotes TI's goal of diversity, efficiency, energy security, and lower greenhouse gas emissions. The reviewer commented that it was the right move and no doubt was fully embraced, and perhaps suggested, by the partnered Clean Cities Coalition and Memphis Light, Gas and Water. The reviewer added that the project has just a handful of partners but the two aforementioned will help champion this effort, and noted that project partners currently meet bimonthly according to the presenter, although there may be times when the group should connect more often (perhaps with weekly calls/emails given the problems they are currently facing).

Reviewer 4

The reviewer commented that the collaboration between the chosen fleet and the technical assistance partners is unclear, and stated that more details on how the ROI and total cost of ownership (TCO) will be evaluated and who will be conducting the evaluations would be helpful.

Question 5: *Energy Equity and Environmental Justice Project Contribution-Please provide comment on the contribution of this project to energy equity and environmental justice by ensuring the project benefits underserved and overburdened communities and does not cause increased burdens to these communities.*

Reviewer 1

The reviewer commented that the project has a goal of changing the County fleet over time, creating a reduction in environmental impacts from the County fleet, and while the fleet is skeptical, the mayor really wants to convert the fleet. The reviewer noted that the mayor is planning on an Executive Order to address the fleet transition, and added that it sounds like it is a bit early in the process to determine the overall impact that could come from this.

Reviewer 2

The reviewer stated that these vehicles, when deployed in underserved areas, will have some benefit such as increasing fuel diversity, but if these vehicles are not replacing current fleet vehicles there will not be an air quality or environmental benefit to these communities. The reviewer also questioned how this project can increase its outreach and education efforts.

Reviewer 3

The reviewer stated that this project is aimed at encouraging the county fleet to replace some of its gas or diesel vehicles with fully electric, and that, if successful, the county will be reducing its production of harmful vehicle emissions, thereby keeping the air cleaner. The reviewer noted that that the area was previously in non-attainment but is no longer, and they are hoping this step will help to keep them out of non-attainment. The reviewer commented that the data collection will be used to determine future purchases, but there does not appear to be a plan to make the information shareable to other fleets to broaden outreach. The reviewer stated that the project is not directly aimed at contributing to energy equity or environment justice.

The reviewer remarked that the data collection includes ROI for vehicles and charging stations, but it is unclear how the charging stations will show a return on investment. The reviewer speculated that it would be perhaps by comparing savings to gas purchases. The reviewer added that it will be tough to show a favorable ROI on the Mach-E, a $43,000 vehicle, especially within the project period. The presenter mentioned that there is reluctance by current fleet people to introduce EVs into the fleet, that it is hoped this pilot will change minds, and that reducing emissions in the county will be enough incentive to consider adding more EVs to the fleet. The reviewer commented that requesting the price of a Mach-E to be put in the county's replacement vehicle budget would be a hard sell, particularly when there are less pricey EVs available.

Reviewer 4

The reviewer commented that the map shows the regions that have higher air toxics in Shelby County and are clearly overburdened with air pollution, and that we can only presume that these communities are underserved as well. The reviewer remarked that sharing information on the driving cycle or usage expected from the five vehicles, as well as the overall fleet usage, would be helpful.

Presentation Number: ti136
Presentation Title: Zero Emission Freight Future
Principal Investigator: Megan Stein, Clean Fuels Ohio

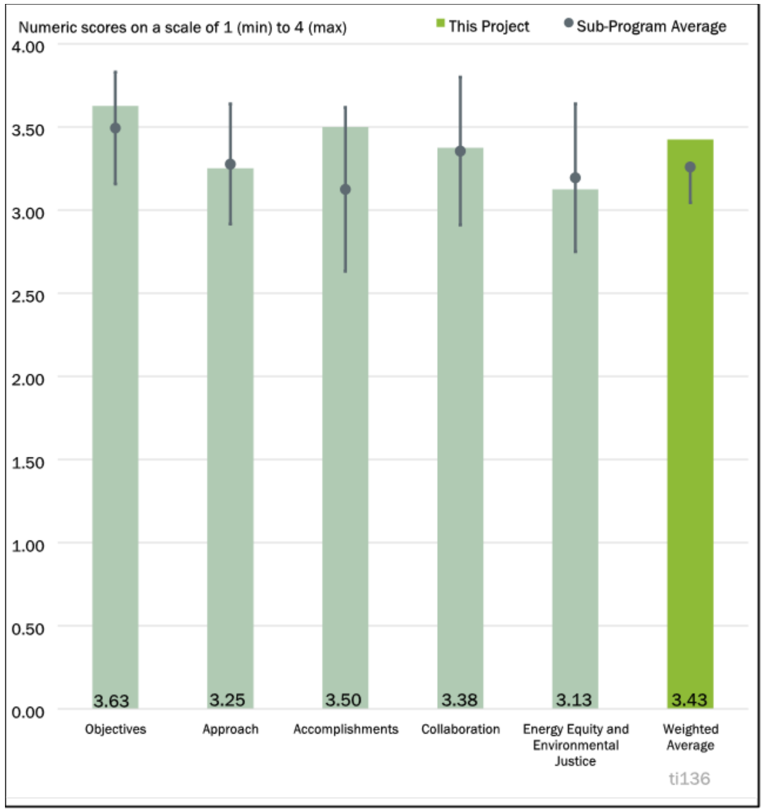

Figure 6-10 - Presentation Number: ti136 Presentation Title: Zero Emission Freight Future Principal Investigator: Megan Stein, Clean Fuels Ohio

Presenter

Megan Stein, Clean Fuels Ohio

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: *Project Objectives—Please provide comments on this project's degree of support for the overall Technology Integration (TI) objectives of improving fuel diversity, increasing local resiliency, and reducing greenhouse gas emissions through increasing alternative fuel use and transportation efficiency.*

Reviewer 1

The reviewer stated that this project meets all of the objectives. It improves fuel diversity, increases local resiliency and reduces GHG emissions through increasing alternative fuel use!

Reviewer 2

The reviewer commented that the project is focused on deploying EVs in MD/HD freight, refuse, and other class 4-8 applications, and that these applications tend to be less familiar, so this project's value is in generating exposure and data in these areas, to allow fleets to begin to adopt EVs. The reviewer stated that, as such, the project is focused on making the operational and financial cases for EVs in these uses, which are often gaps in the existing knowledge base.

Reviewer 3

The reviewer remarked that the project will collect data and document successes of and issues with Class 7 and Class 8 EVs, an area that needs more input before there is widespread adoption. The reviewer added that use of these vehicles will reduce greenhouse gas emissions and increase transportation efficiency, and further noted that the analysis findings and tools will be disseminated for replication.

The reviewer commented that it is not indicated where these tools will reside after the end date of this project; it is hoped that the information will be easily accessible to other fleets.

Reviewer 4

The reviewer commented that the project is closely supporting the overall TI objectives by evaluating the integration and demonstration of three MD and HD electric trucks in different applications: a step van for bakery delivery, a refuse truck, and class 8 straight trucks in Columbus, OH. The objective is to increase deployment of MD and HD EVs through the experience and data collection and analysis of their performance.

Question 2: *Project Approach-Please comment on this project's approach for integrating advanced transportation technologies and practices to solve real-world challenges.*

Reviewer 1

The reviewer praised this project, as it meets all of the objectives, looks into an area that needs a good deal more research, and had great equity considerations. The reviewer noted that it is looking at three different use cases as well, and suggested that the only improvement might be scrapping the vehicles that were replaced in the fleets, therefore reducing GHG emissions overall, instead of moving the emissions to a different fleet.

Reviewer 2

The reviewer commented that the project has a very straightforward approach laid out, focused on deploying EVs and EVSE plus data collection and analysis. The reviewer noted that the plan includes development of a model tool for analysis, based upon 3 months of data, and had a concern that this short period might not sufficiently account for weather variations. The reviewer added that, at this time, it is also a bit unclear what the special value is of the new tool vs. what is out there now.

Reviewer 3

The reviewer remarked that the PI presented an excellent game plan to achieve the goals of this project: Clean Fuels Ohio (CFO) has partnered with Sawatch Labs to develop analysis tools and resources. Prior to the ordering and deployment of the vehicles, CFO tapped into its Project Advisory Committee for feedback on analysis and vehicle specifications. They created a data collection and engineering and deployment plan. After the vehicles are deployed, they will follow through with data collection, demonstrations, and the development of tools and resources for other fleets. The reviewer found that the approach is thorough, thoughtful, and directly addresses the objective of increasing knowledge of HD EVs, leading to an eventual increase in vehicle purchases by area fleets.

Reviewer 4

The reviewer commented that the project approach is well laid out: deploy the MD and HD EVs, demonstrate them and collect data, and develop an analysis model tool. The reviewer found the model tool to be one of the more interesting aspects of the project as its purpose is to support fleets that are considering a transition to EVs to determine if it makes sense and which models would suit the fleets' needs best.

The reviewer remarked that the EV analysis model tool was insufficiently described, however, and that it was unclear what types of data collected will inform the tool. The reviewer noted that Sawatch Labs is gathering the data from the OEMs and developing the tool, but how the developed tool would be used in the future is unclear. The reviewer questioned whether the tool would be provided as a free tool to fleets (given it is developed with public funding) or if it is a tool that would help Sawatch Labs conduct consulting work in the future. The reviewer indicated that more information on the type of tool, and where it will be available is needed.

Question 3: *Project Accomplishments and Progress-Please comment on the project's progress and significant accomplishments to date.*

Reviewer 1

The reviewer stated that the project is well underway and has achieved its goals so far.

Reviewer 2

The reviewer commented that the presentation appears to indicate that milestones are on track, but the principal investigator indicated that deliveries of EVs have been delayed primarily due to supply chain issues. (The step van and refuse truck are delayed until early 2023, while the Volvo straight truck was delivered in April 2022.) The reviewer noted that, in the meantime, the project has been developing its data collection and analysis plan and begun collecting data on control vehicles. They are also looking at national data to influence analysis tool development, and they have received commitments from fleets on data. The reviewer stated that it appears that the tool developer will require 3 months of data.

Reviewer 3

The reviewer noted that project milestones are 50% complete, and on target. One vehicle was received in April and data is being gathered, and once all vehicles are received and data collected, tools and resources will be made available for replication of this pilot.

The reviewer commented that it appears the only issue has been the delay of the vehicles, which pushes back the gathering of data. The other two vehicles will be delivered later in the year. The reviewer suggested that the project's data collecting period may need to be extended beyond the project end date to gather enough data on the vehicles for accurate analysis.

Reviewer 4

The reviewer commented that the vehicles have been either purchased or deployed, together with the EVSE, and a data collection and analysis plan was created. The reviewer found the main drawback to be a lack of information on the tool that will be developed, and requested that the PI provide more details on the tool and how it and other replication resources will be implemented at the end of the project.

Question 4: *Collaboration and Coordination Among Project Team—Please comment on the level of collaboration within the project team and the degree to which the project team has identified and leveraged the proper connections to achieve its project goals.*

Reviewer 1

The reviewer applauded the great project team and collaboration.

Reviewer 2

The reviewer commented that CFO has an impressive team that goes beyond the primary partners, and its Project Advisory Committee consists of those experienced in fleets and the industry. The reviewer added that the project's primary partners are established companies, and the original equipment manufacturer (OEM) and technical partners are knowledgeable and dedicated to the project.

Reviewer 3

The reviewer noted that the project includes involvement of Clean Fuels Ohio, Sawatch Labs, PittOhio, Bimbo Bakeries, the City of Columbus, and vehicle manufacturers, and that the operational site for these vehicles is specifically for an overburdened area. The reviewer noted that each fleet was responsible for contracting for EVSE installations on their own, so no EVSE partners were explicitly part of the project.

Reviewer 4

The reviewer noted that the collaboration is overall good, or seems good. The reviewer commented that the impact of the tool and plans that Sawatch Labs has should be explained, and questioned whether there are meetings where the three fleets in question share experiences and provide learnings. The reviewer recommended exposing additional fleets to the results to disseminate the information outside of the named project fleets more broadly.

Question 5: Energy Equity and Environmental Justice Project Contribution-Please provide comment on the contribution of this project to energy equity and environmental justice by ensuring the project benefits underserved and overburdened communities and does not cause increased burdens to these communities.

Reviewer 1

The reviewer noted that the vehicles were all deployed in underserved/overburdened areas, and commended the project team on a great job. The reviewer suggested that there could have been more details about this in the presentation.

Reviewer 2

The reviewer stated that if EVs in these applications can take off, there can be significant energy equity/environmental justice benefits, as many of these vehicles operate in compromised areas. The reviewer added that the deployment sites in the project were specifically selected as overburdened areas.

Reviewer 3

The reviewer remarked that, while not directly targeted to support underserved and overburdened communities, replication of this pilot will help to reduce greenhouse gases and improve air quality in all communities, including disadvantaged. The reviewer added that this project is also in line with the City of Columbus's Climate Action Plan.

Reviewer 4

The reviewer commented that, while electric MD and HD vehicles provide zero emission operation and can benefit communities, the project does not sufficiently demonstrate which communities overburdened with pollution will benefit during this project and how energy equity and environmental justice will be positively impacted.

Presentation Number: ti137
Presentation Title: Cold-Weather Operation, Observation and Learning Electric Vehicles
Principal Investigator: Lisa Thurstin, American Lung Association

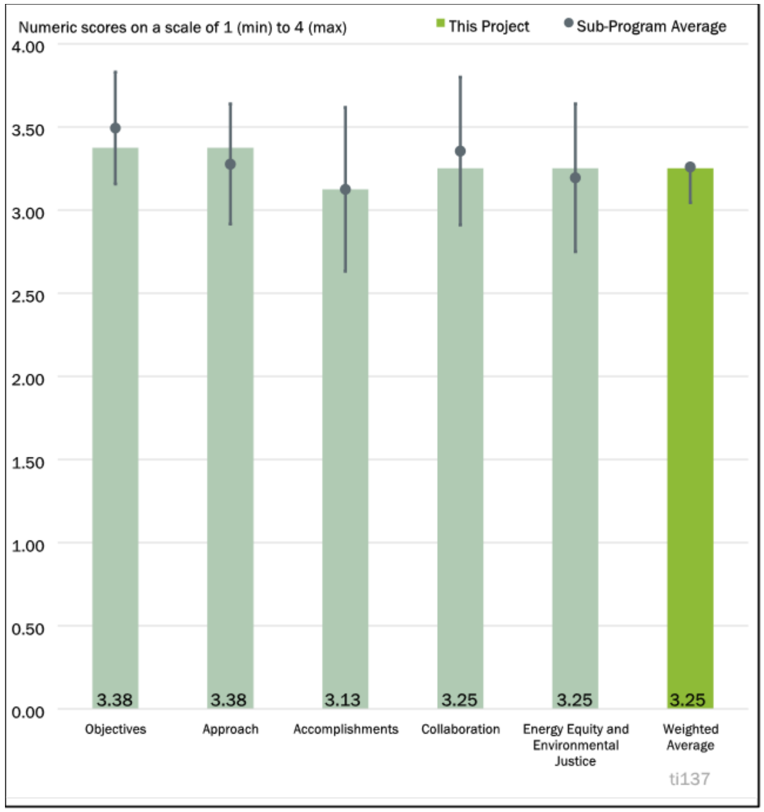

Figure 6-11 - Presentation Number: ti137 Presentation Title: Cold-Weather Operation, Observation and Learning Electric Vehicles Principal Investigator: Lisa Thurstin, American Lung Association

Presenter

Lisa Thurstin, American Lung Association

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: *Project Objectives—Please provide comments on this project's degree of support for the overall Technology Integration (TI) objectives of improving fuel diversity, increasing local resiliency, and reducing greenhouse gas emissions through increasing alternative fuel use and transportation efficiency.*

Reviewer 1

The reviewer commented that this project is specifically focused on generating cold-weather data on MD/HD EVs, a critical need. The reviewer noted that the project has several different types of vehicles involved, too, including school bus, transit bus, delivery, and recycling vehicles, and added that getting quality cold-weather data on EVs will be very important for allowing EVs to move into operation in more localities.

Reviewer 2

The reviewer noted that the project meets the needs of TI by deploying and evaluating four EVs in three different fleets along with the associated EV charging infrastructure. The reviewer added that the specific topic to be studied is EV operation in cold weather environments, which is an important consideration for many regions.

Reviewer 3

The reviewer commented that this project seeks to address the main reason progressive fleets located in colder climates have EV hesitancy, and noted the value of locating the pilot in Minnesota, where the temperatures frequently go below 0° in the winter months. The reviewer noted that data from this project will inform TI of issues that can be addressed in its work with OEMs and when providing funding opportunities to improve the technology and EV experience. The presenter mentioned that recent hot weather in Minnesota will allow this project to also gather data on MD/HD EVs in the hotter months. The reviewer found this to be useful, and noted that the data from this project will help fleet managers from Idaho to Maine make informed decisions and choices, increasing the chances of a positive EV experience. The reviewer added that positive experiences lead to more EV purchases, and more happy fleets mean more purchases of alternative fuels and, ultimately, lower greenhouse gas emissions.

Reviewer 4

The reviewer stated that deployment and evaluation of MD and HD EVs with new fleets are important steps that will lead to a reduction of greenhouse gas emissions, fuel diversity and resiliency.

The reviewer commented that on Slide 3, Project Objectives, an item stating the project will provide best practices for one-way and two-way carshare was not clear and was not mentioned anywhere later in the project, and needs clarification.

Question 2: *Project Approach-Please comment on this project's approach for integrating advanced transportation technologies and practices to solve real-world challenges.*

Reviewer 1

The reviewer commented that the approach is solid—deploy 4 MD/HD EVs, supported by data collection/analysis and outreach, and added that the applications include school buses and recycling collection. The reviewer noted that outreach and education has been a strong part of the project, to date focused heavily on the school bus.

Reviewer 2

The reviewer stated that more information on the specific data that will be collected and the specific analyses that will be conducted would be helpful, especially, the particular metrics that will be used to assess performance in cold weather conditions. The reviewer noted that this information was not presented during the AMR.

Reviewer 3

The reviewer commented that, on its face, the project is simple: deploy MD/HD EVs and gather data on operation in the crippling cold (and when very hot). The reviewer added that the approach is direct: gather partners, choose vehicles, install EVSE, get vehicles, gather data while implementing training and outreach, and noted that the PI wields years of experience, so even losing a partner mid-project, and supply chain shortages and pandemic-related delays do not affect the foundation of the project's objectives. The reviewer added that the PI researched which vehicles in these classes would be the best fit, given service locations and other considerations to ensure reliability for data collecting and operation.

Reviewer 4

The reviewer remarked that evaluating the cold weather performance is important clearly for fleets in Minnesota, but stated that more details on the evaluation process of cold weather performance should be included The reviewer added that including dissemination of learning to other local fleets in the region, perhaps through the Clean Cities relationships, would be very helpful and is recommended.

Question 3: *Project Accomplishments and Progress-Please comment on the project's progress and significant accomplishments to date.*

Reviewer 1

The reviewer noted that although only one of the four vehicles has been deployed, all other milestones and targets are on track. The reviewer added that the school bus has already been part of demonstrations and there is no doubt once the other three vehicles are received, the balance of tasks will be underway quickly.

Reviewer 2

The reviewer noted that the overall project progress has been delayed by the supply chain issues; however, the school system was able to deploy the EV bus and has been using it in operation and collecting data.

Reviewer 3

The reviewer noted that the project had one fleet back out and needed to bring in a new one, which resulted in some delays, and the project team did learn a lot along the way on how to carefully select the EVs as well as charging; these had some impacts on procurement and budget, and deliveries for two of the fleets have been delayed. The reviewer commented that the school district has had its Blue Bird bus on the road since last August and that there was no route optimization work before it went into operation, but that will now happen this summer. The reviewer added that they have done a number of outreach and education events, exposing a lot of fleets to EV technologies. The plan is to potentially ask for a project extension to allow for keeping a six-month period for data collection.

Reviewer 4

The reviewer stated that the e-school bus has been deployed and two other vehicles on order, which is encouraging, but it is not clear what the fourth fleet is. The reviewer recommended that details on performance monitoring be included, given the focus on cold weather evaluation.

Question 4: *Collaboration and Coordination Among Project Team—Please comment on the level of collaboration within the project team and the degree to which the project team has identified and leveraged the proper connections to achieve its project goals.*

Reviewer 1

The reviewer noted that this project involves just a handful of partners, however most partners on this project have had a longstanding relationship with Minnesota Clean Cities. The reviewer added that the PI is very experienced with outreach, and the data/information will be shared, although it was not clear where the resulting case study will wind up after the project end date. The reviewer expressed hope that the information and experiences gathered will continue to be accessible to fleets.

Reviewer 2

The reviewer commented that the partners include the fleets (although one changed), the utility, and CTE (technical assistance), and noted that the team had to work carefully to replace one fleet, which had cancelled due to COVID-19 and staffing. The reviewer stated that twelve fleets were interviewed to replace the departing fleet, the University of Minnesota was selected as the replacement, and the team will continue relationships with the non-selected fleets for future involvement. The Principal Investigator (PI) indicated that the reason they were able to successfully replace the fleet that pulled out was that the PI has an on-going list of projects and partners built through the Clean Cities Coalition’s strong relationships in the local fleet community, and the reviewer stated that this provided an important starting point for reaching out to potential replacements.

Question 5: *Energy Equity and Environmental Justice Project Contribution-Please provide comment on the contribution of this project to energy equity and environmental justice by ensuring the project benefits underserved and overburdened communities and does not cause increased burdens to these communities.*

Reviewer 1

The reviewer remarked that the PI indicated the vehicles will be deployed in two communities of low income and that case studies/demonstrations will be provided to underserved communities. The reviewer added that the long-term benefit here would be the increase in the adoption of MD/HD EVs that frequent these communities (local company trucks and school buses for instance), which would lead to lower emissions in the overburdened communities.

Reviewer 2

The reviewer noted that two of the three communities where the vehicles will be deployed are low-income communities, and the project case studies and demonstrations are being targeted to underserved communities.

Reviewer 3

The reviewer commented that if the vehicles succeed, they will be in applications that will result in significant improvements in disadvantaged and compromised communities. The reviewer noted that several of the communities selected for the project are low-income and the project plans to develop case studies and demonstrations to benefit under-served communities.

Reviewer 4

The reviewer echoed an earlier recommendation to include other regional fleets in the outreach and dissemination of learning and stated that more and increased focus on addressing equity for the communities most in need is highly recommended. The reviewer suggested developing a specific plan for the desired outcome in terms of equity and environmental justice.

Presentation Number: ti138
Presentation Title: Demonstrating Electric Shuttles for the New Orleans Region
Principal Investigator: Elizabeth Davey, Tulane University

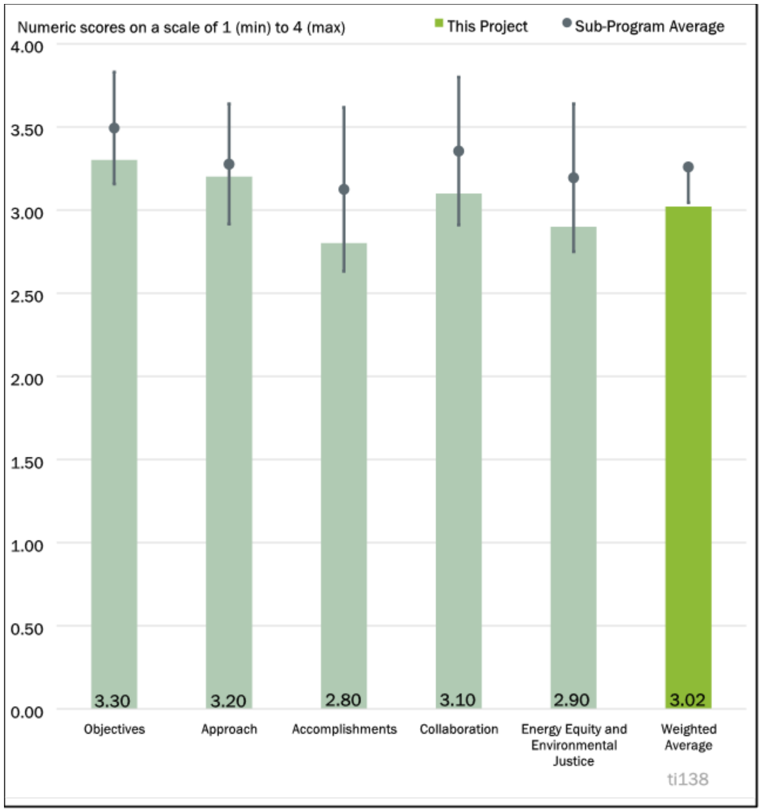

Figure 6-12 - Presentation Number: ti138 Presentation Title: Demonstrating Electric Shuttles for the New Orleans Region Principal Investigator: Elizabeth Davey, Tulane University

Presenter

Elizabeth Davey, Tulane University

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: *Project Objectives—Please provide comments on this project's degree of support for the overall Technology Integration (TI) objectives of improving fuel diversity, increasing local resiliency, and reducing greenhouse gas emissions through increasing alternative fuel use and transportation efficiency.*

Reviewer 1

The reviewer stated that this project deploys electric shuttle busses, which directly reduce the use of conventional fuels and emissions and added that outreach and education connected to the projects should expand the impact.

Reviewer 2

The reviewer remarked that the project is focused on overcoming limited local experience with EVs among local shuttle operators, contractors, and the utility, and that this is important to providing an opportunity for growth in the region. In addition, there is little data currently available. The reviewer noted that the fleet has 10 shuttles in operation, ranging from 20-40 passengers, and commented that there are a number of similar-size shuttles operating in the area and the project is focused on sharing data with them.

Reviewer 3

The reviewer stated that 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 improving fuel diversity by adding electric vehicles to the Tulane University campus shuttle fleet and reducing greenhouse gas emissions by shifting to electricity increasingly sourced from clean and renewable sources. The reviewer commented that the project objectives appear to be generally effective for the planned scope.

Reviewer 4

The reviewer remarked that EV shuttles for Tulane University will be a good example of electric MD and HD vehicles.

Reviewer 5

The reviewer stated that this project meets all TI objectives, but it could go further in reducing barriers.

Question 2: *Project Approach-Please comment on this project's approach for integrating advanced transportation technologies and practices to solve real-world challenges.*

Reviewer 1

The reviewer noted that 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 improving fuel diversity by adding electric vehicles to the Tulane University campus shuttle fleet and reducing greenhouse gas emissions by shifting to electricity increasingly sourced from clean and renewable sources. The reviewer found that the project objectives appear to be generally effective for the planned scope.

Reviewer 2

The reviewer commented that the project approach is simple: procure electric vehicles, deploy those vehicles and collect data, and then conduct data analysis and outreach; in particular, significant outreach within the local community is planned. The reviewer noted that the project planned for one charger per bus; because of the duty cycle, the fleet was interested in being able to charge all at the same time. They did not even look at L2 charging, as they had assumed the chargers were coming with the EVs, due to lack of experience. The reviewer noted that they are now considering what their back-up plan might be, particularly in the case of emergency. The reviewer observed that the University has a combined heat and power (microgrid) system, so it can provide power in the case of emergency. The reviewer stated that the plan is for six to nine months of data collection for analysis, which should work for performance, but might not be long enough for maintenance.

Reviewer 3

The reviewer stated that this is a very interesting evaluation of impact that includes carbon pricing, and looks forward to seeing more details on that.

Reviewer 4

The reviewer remarked that the project team had to deal with a change in vehicle vendor and COVID-19 related impacts that have delayed project deployment.

Reviewer 5

The reviewer expressed appreciation for what this project is doing for the University, but felt that more dissemination is necessary to be able to claim that these shuttles are a demonstration for the entire New Orleans region.

Question 3: *Project Accomplishments and Progress-Please comment on the project's progress and significant accomplishments to date.*

Reviewer 1

The reviewer commented that the project has made significant progress even in the face of Hurricane Ida and supply chain constraints.

Reviewer 2

The reviewer stated that satisfactory progress has been made towards achieving project goals, taking into account delays associated with supply chain disruptions/price increases and the continued COVID-19 pandemic. The reviewer added that the project has made progress on several key activities: Four Lightning

Electric E-450 shuttle buses are on order with an expected delivery in December 2022; and the five DC fast chargers site work has been completed and will soon be operational.

The reviewer noted that delays associated with cost increases and vehicle availability resulted in the project scope being changed from the deployment of five to four electric shuttles.

Reviewer 3

The reviewer commented that the delayed delivery of the vehicles has prevented the project from presenting actual results beyond the infrastructure deployment.

Reviewer 4

The reviewer remarked that BP1 tasks were focused on procurement and EVSE design, the EVSE has not been installed or commissioned, and the vehicles have not been received, due to supply chain delays. The reviewer stated that working through procurement has been a bit of a nightmare. They put in the order for buses, but during the delay, the bus supplier was purchased and the new owner indicated a very significant (60%) price increase, and there was a concern that the higher price would mean higher insurance prices. The reviewer noted that the project team fully vetted the Lightning Electric E-450 shuttles, then put in a purchase order in June 2022 for delivery now in December 2022.

The reviewer commented that the EVSE site has been fully planned, which took some effort. Five ABB 50 kW fast chargers will be installed and have already been procured. The reviewer noted that the utility and contractor were able to accomplish all the site preparation work and chargers will be installed as the vehicles approach. There was a bit of a delay in construction due to Hurricane Ida.

Reviewer 5

The reviewer commented that the infrastructure is currently being installed, and noted that the amount of funding that has been spent to date is not that significant, given all the infrastructure installation costs. The reviewer questioned whether there will be enough time to complete the evaluation once the vehicles arrive.

Question 4: *Collaboration and Coordination Among Project Team—Please comment on the level of collaboration within the project team and the degree to which the project team has identified and leveraged the proper connections to achieve its project goals.*

Reviewer 1

The reviewer remarked that the project has a great project team.

Reviewer 2

The reviewer stated that there was good teaming collaboration within the university itself and with the utility and Clean Cities.

Reviewer 3

The reviewer noted that the partners include Clean Cities, the fleet (Tulane), the utility, and the bus dealer, and there are three offices within Tulane participating, with assistance of a few others. The reviewer added that the utility has designated one point of contact for the project and the new bus supplier has become a partner in the project.

Reviewer 4

The reviewer commented that it is a satisfactory project team including Tulane University, Entergy New Orleans, the local bus provider (Creative Bus Sales), and the local Clean Cities coalition (Southeast Louisiana Clean Fuel Partnership) that has been assembled to carry out this project and provide an appropriate mix of expertise among team members. The reviewer remarked that the project would have benefited from an active role by community-based organizations, which appear to be missing from the project team. The reviewer added that collaboration/ communication among project partners appears to be appropriate for a project of this scope.

Reviewer 5

The reviewer commented that the project team seemed to be in frequent conversations around project status; however, the original vehicle vendors could have communicated earlier as it became clear they would be unable to deliver the vehicles as ordered.

Question 5: *Energy Equity and Environmental Justice Project Contribution-Please provide comment on the contribution of this project to energy equity and environmental justice by ensuring the project benefits underserved and overburdened communities and does not cause increased burdens to these communities.*

Reviewer 1

The reviewer noted that the project specifically includes a financial analysis with carbon pricing, to identify the full impacts on the community and added that the project is demonstrating the replacement of diesels with EVs to improve air quality in a majority-minority city. The reviewer commented that Entergy has a Renewable and Clean Energy Portfolio Standard so that future electric vehicles will operate on cleaner electricity, further benefiting the community, and there is interest in opening charging stations to selected additional fleets to help expand EV adoption.

Reviewer 2

The reviewer stated that the shuttle buses will be operating in area with underserved and impacted communities and added that the next step from this project would be to see how other bus services in the city can take this example and implement EV shuttle buses in their operations.

Reviewer 3

The reviewer commented that demonstration events and further dissemination of the project and related lessons learned would improve the project and bring the project closer to meeting its objectives.

Reviewer 4

The reviewer remarked that the project has good potential to contribute to energy equity and environmental justice goals by increasing transportation efficiency by demonstrating the replacement of diesel vehicles with zero emission EVs, fostering action to improve local air quality in a city with a majority Black population. The reviewer suggested that the project would have benefited from including community-based organizations, to help provide local priorities for this project and similar ones that may be undertaken. The reviewer stated that, until the deployment of the project is up and running at full capacity and the anticipated results are documented, it is difficult to evaluate the effectiveness of the project.

Reviewer 5

The reviewer expressed the view that, while the vehicle deployments and outreach will have some impacts to EEJ communities, the project could have done more to include EEJ community representatives on the team to ensure benefits were maximized.

Presentation Number: ti139 Presentation Title: Pilot Heavy-Duty Electric Vehicle (EV) Deployment for Municipal Solid Waste Collection Principal Investigator: Shaina Kilcoyne, Municipality of Anchorage

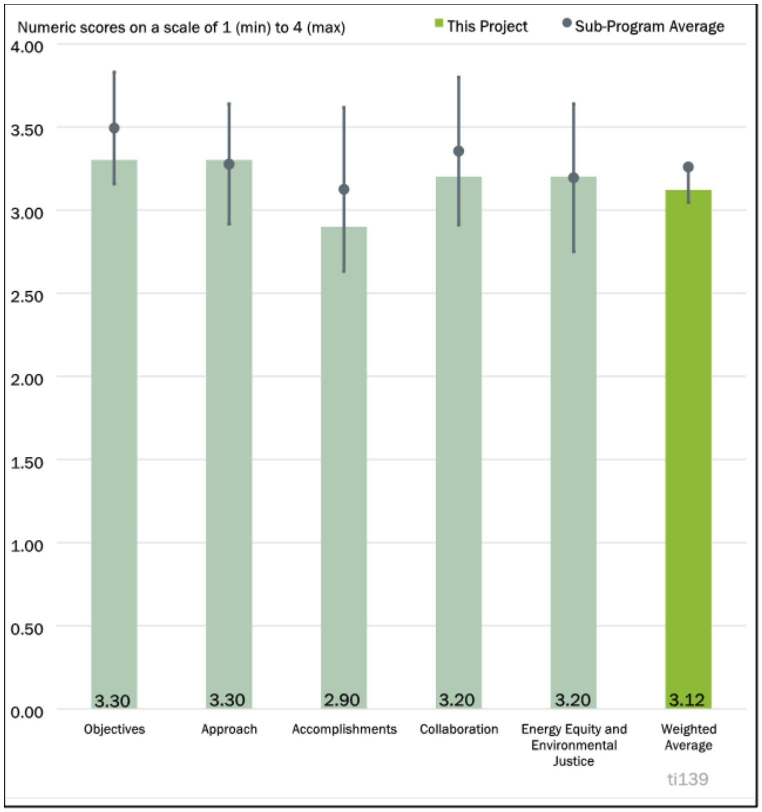

Figure 6-13 - Presentation Number: ti139 Presentation Title: Pilot Heavy-Duty Electric Vehicle (EV) Deployment for Municipal Solid Waste Collection Principal Investigator: Shaina Kilcoyne, Municipality of Anchorage

Presenter

Shaina Kilcoyne, Muncipality of Anchorage

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: *Project Objectives—Please provide comments on this project's degree of support for the overall Technology Integration (TI) objectives of improving fuel diversity, increasing local resiliency, and reducing greenhouse gas emissions through increasing alternative fuel use and transportation efficiency.*

Reviewer 1

The reviewer stated that this project meets all three TI objectives in a clever and unique way.

Reviewer 2

The reviewer observed that the project is focused on cold-climate performance of MD/HD EVs, with an additional element focused on reduction of demand charges through managed charging. (Anchorage demand charges are $23/kW, with double that in other parts of Alaska.) The reviewer stated that the results of this project could not only show others in similar climates that EVs can work, but also how to operate them to provide additional benefits.

Reviewer 3

The reviewer commented that 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 improving fuel diversity, increasing local resiliency, and reducing greenhouse gas emissions by deploying three MD/HD electric vehicles (two garbage trucks and one box truck) in the City of Anchorage's municipal fleet. The reviewer added that the project objectives appear to be generally effective for the planned scope.

Reviewer 4

The reviewer remarked that this is important work to look at performance in cold climates for electric HD vehicles and to focus on workforce development.

Reviewer 5

The reviewer commented that the project addresses the refuse sector, which is a promising target for electrification but has limited deployments to date. The reviewer added that measuring the cold weather performance of these vehicles can give confidence to operators in all climates that these vehicles will meet performance specifications.

Question 2: *Project Approach-Please comment on this project's approach for integrating advanced transportation technologies and practices to solve real-world challenges.*

Reviewer 1

The reviewer complimented the overall approach as being well organized with planning, demonstrations and evaluation. The reviewer noted that the inclusion of a box truck in addition to the refuse trucks allowed some project activities to proceed while waiting for the refuse truck delivery.

Reviewer 2

The reviewer commented that this is a basic approach to demonstration, although they did have a box truck already in place which allowed for efforts in advance of the arrival of the newly-procured refuse trucks. The reviewer observed that, because of their rate situation, they are looking at charging strategy very carefully.

Reviewer 3

The reviewer stated that the project approach section provides a satisfactory methodology to accomplishing the project objectives and supporting the integration of advanced transportation technologies and practices. The project approach is divided by three project periods (Initiate Pilot Deployment, Monitor Pilot Deployment, and Continued Equipment Maintenance) each containing associated tasks and go/no-go decision points. The reviewer added that the Milestone slide provides adequate detail with regard to the planned tasks per Budget Periods and progress to date.

Reviewer 4

The reviewer remarked that this is an impressive project on deploying EV HD vehicles in Alaska together with batteries for peak shaving and future proofing the installation. The reviewer noted that it was interesting to hear that the decision in selecting vehicles was determined by the availability of service support in the region, an interesting point that the reviewer suggested should be communicated to the manufacturers.

Reviewer 5

The reviewer stated that this is a great and well thought out project. The reviewer suggested that the project could be improved by scrapping the vehicles that the new vehicles replaced, to have an overall reduction of GHG, instead of moving the emissions to another fleet, and including a workforce development plan to train local technicians to be able to work on the vehicles and charging equipment instead of having to have a technician fly in. The reviewer added that the First Responder Training for EVs from the National Association of Fleet Administrators (NAFA) would be a great tie in here.

Question 3: *Project Accomplishments and Progress-Please comment on the project's progress and significant accomplishments to date.*

Reviewer 1

The reviewer commented that the project was able to proceed through early stages while waiting on the delivery of refuse trucks; the project made good use of this additional time to plan for additional infrastructure installation and new refuse facility.

Reviewer 2

The reviewer noted some delays that seem to be related to supply chain delays. The reviewer commented that future proofing of the site is very good enabling it for the next phases.

Reviewer 3

The reviewer commented that the project vetted EV options and chose their existing supplier (Peterbilt), which has a facility in Anchorage, and noted that they did find that some manufacturers did not want to sell only 1-2 vehicles (offering a minimum of 10), but added that some efforts have started using the existing box truck. The reviewer observed that the team spent a lot of effort on EVSE design for the specific conditions for the project, as well as future-proofing the system, and noted that their EVSE includes a battery to allow for spreading load further. The reviewer observed that, as a bit of a break-through, the team has developed what they believe is a lower-cost approach for incorporating EVSE-ready technical needs, which they are planning to share with other local fleet operators.

The reviewer noted that there have been some issues with the box truck since it is only two-wheel-drive, and that has impacted operational use and made data analysis challenging.

Reviewer 4

The reviewer commented that this project is as far along as it can be given the supply chain delays.

Reviewer 5

The reviewer remarked that fair progress has been made towards achieving project goals, taking into account delays associated with delivery of the electric garbage trucks, which have not yet been delivered/deployed. The reviewer found that the project has made progress on several key activities: The electric box truck has been delivered, and Solid Waste Services laid conduit pathways to five bays from the battery and to seven bays from the electrical room.

The reviewer noted that the project also includes battery storage to mitigate significant demand charges, however the battery has still not arrived. The reviewer added that the EV chargers are not installed/operational, and much of the project appears to be behind schedule at this point.

Question 4: *Collaboration and Coordination Among Project Team—Please comment on the level of collaboration within the project team and the degree to which the project team has identified and leveraged the proper connections to achieve its project goals.*

Reviewer 1

The reviewer praised the great team.

Reviewer 2

The reviewer praised the great collaboration between team members.

Reviewer 3

The reviewer commented that the project team displays good collaboration between the City, the Utility, the academic community and the technology providers.

Reviewer 4

The reviewer noted that partners include the Alaska Energy Authority and Alaska Center for Energy and Power, as well as eCamion (charging station), and stated that these are useful partners, but more partners on board to provide a greater element for outreach could have been useful. The reviewer found that, in particular, the project team has found Peterbilt to be very responsive.

Reviewer 5

The reviewer stated that a satisfactory project team including City of Anchorage's Solid Waste Services, the Alaska Energy Authority, University of Alaska Fairbanks/Alaska Center for Energy & Power, and the local truck provider (Peterbilt) are assembled to carry out this project and provide an appropriate mix of expertise among team members. The reviewer suggested, however, that the project would have benefited from an active role by community-based organizations, which appear to be missing from the project team The reviewer found that collaboration/communication among project partners appears to be appropriate for the project of this scope.

Question 5: *Energy Equity and Environmental Justice Project Contribution-Please provide comment on the contribution of this project to energy equity and environmental justice by ensuring the project benefits underserved and overburdened communities and does not cause increased burdens to these communities.*

Reviewer 1

The reviewer observed that parts of the project area include very high asthma rates and other environmental concerns and stated that the electric refuse haulers should benefit this area significantly, particularly if this project leads to greater deployments. The reviewer noted that the route is also designated as an alternative fuel corridor, eligible for Federal funding and observed that, in 2020 at the time of application, diesel was priced at $2.85/gal versus $5.14/gal in June, therefore, resulting in sizable energy cost savings for the project.

Reviewer 2

The reviewer observed that the units will be operating in corridors that are affected heavily by pollution.

Reviewer 3

The reviewer observed that refuse routes include communities most impacted by poor air quality, and the additional EV readiness added to the refuse facility will allow additional expansion of the electric fleet if the demonstrations proves feasible.

Reviewer 4

The reviewer commented that the project has a satisfactory potential to contribute to energy equity and environmental justice goals by replacing diesel vehicles with zero emission EVs, which will result in improving local air quality. The reviewer noted that Solid Waste Services' service territory includes areas with the highest asthma rates and health insurance stress, including much of Mountain View along the highway to the landfill, and stated that electric garbage trucks will reduce pollution along this corridor. The reviewer suggested that the project would have benefited from including community-based organizations, to help provide local priorities for this project and similar ones that may be undertaken. The reviewer stated that, until the deployment of the project is up and running at full capacity and the anticipated results are documented, it is difficult to evaluate the effectiveness of the project.

Reviewer 5

The reviewer praised the fact that these vehicles were deployed on corridors of high asthma rates and high insurance burden. The reviewer wondered about further ensuring the demos, and whether information sharing is reaching fleet managers in overburdened and under resourced communities.

Presentation Number: ti140
Presentation Title: St. Louis Vehicle Electrification Rides for Seniors
Principal Investigator: Connor Herman, Forth Mobility

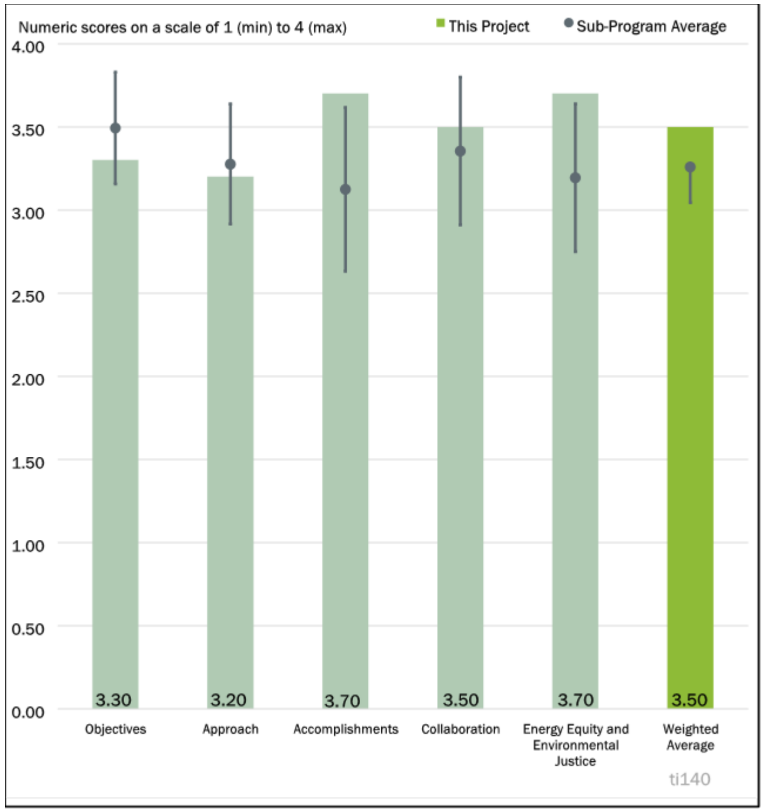

Figure 6-14 - Presentation Number: ti140 Presentation Title: St. Louis Vehicle Electrification Rides for Seniors Principal Investigator: Connor Herman, Forth Mobility

Presenter

Connor Herman, Forth Mobility

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: *Project Objectives—Please provide comments on this project's degree of support for the overall Technology Integration (TI) objectives of improving fuel diversity, increasing local resiliency, and reducing greenhouse gas emissions through increasing alternative fuel use and transportation efficiency.*

Reviewer 1

The reviewer indicated that the project has strong objectives in measuring if and how EV fleets can serve social service agencies, save money and improve service delivery, and added that it is a model for deploying EVSE that serves both fleets and community members.

Reviewer 2

The reviewer commented that this effort examines the viability of electric vehicles for smaller nonprofits, specifically community-based organizations (CBOs) that do not have capacity to analyze TCO of installing charging and using EVs, and added that, if successful, this would provide a model for small fleets that do not have a fleet manager to utilize EVs. In addition, as CBOs work with local community members, the successful use of EVs could lead to further EV deployment through word-of-mouth. The reviewer stated that, in that case, the project could improve local fuel diversity and resiliency, as well as reduce greenhouse gas emissions due to the low emission profile of electric vehicles.

Reviewer 3

The reviewer noted that 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 improving fuel diversity by adding electric vehicles and charging to two community-based organization's fleets (Northside Youth & Senior Center and City Seniors, Inc.). The reviewer added that the project will measure how EV fleets can save community-based organizations and social service agencies money and improve service delivery and create a model for deploying EVSE that serves those fleets and can also serve employees and community members. The reviewer commented that the Project Objectives appear to be generally effective for the planned scope.

Reviewer 4

The reviewer praised the project and said it meets the objectives of improving fuel diversity and increasing local resiliency. The reviewer indicated that it is not clear whether these vehicles were replacement vehicles or additional vehicles for the fleet, and whether the reducing GHG emissions objective is being met.

Reviewer 5

The reviewer commented on a positive outcome of this project—helping seniors and resolving the issue of volunteers having to use their own vehicles. The reviewer stated that the project helps to support technology integration objectives of improving fuel diversity by adding these five Chevy Bolts to organizations that at the time had no vehicles to provide to their volunteers, thereby exposing the area to a cleaner vehicle technology. The reviewer added that EVs help transportation efficiency and adding them to community organizations for seniors based in a lower socio-economic area furthers efforts to assist underserved and overburden populations.

The reviewer noted that the insurance is currently paid for by Forth and it is assumed that the expense will be the responsibility of the CBO when the project period ends. The reviewer commented that the insurance, maintenance, repair and cost of electricity for the EVs, and EVSE management and maintenance may be more than the community-based organization (CBO) can bear once the project ends, and added that for smaller agencies with bare bones budgets (which at present rely on volunteer drivers and their vehicles), owning EVs may be cost prohibitive, particularly if gas prices go down. The reviewer opined that adding vehicle ownership to programs that are currently working adequately using volunteer vehicles may be a hard sell if there is not an appealing ROI. It is hoped that other organizations will step in and assist if needed so this program can continue.

Question 2: *Project Approach-Please comment on this project's approach for integrating advanced transportation technologies and practices to solve real-world challenges.*

Reviewer 1

The reviewer observed that the project approach section provides an excellent methodology to accomplish the project objectives and support the integration of advanced transportation technologies and practices. The reviewer noted that the project approach is divided by three project periods (Project Initiation and Launch, Project Refinement, and Project Wrap-up & Results Dissemination), each containing associated tasks and applicable go/no-go decision points, and added that the Milestone slide provides significant detail with regards to the planned tasks per budget periods and progress to date.

Reviewer 2

The reviewer noted that the project aims to measure the costs and benefits of EV fleets in social service agencies to improve delivery of service and to produce a case study in hopes the practice will be replicated. The reviewer stated that, for agencies with funds and a desire to own and maintain their own vehicles, this is a much needed pilot and they eagerly await the case study. The reviewer commented that the approach is simple and direct: procure vehicles, install charging stations, train staff, launch program, gather data, conduct workshops/outreach, produce and share model/case study.

Reviewer 3

The reviewer remarked that the approach was logical in planning for deployments, conducting outreach, deploying the vehicles and monitoring impacts, and the program design with sites in the north and south of the city gives an interesting opportunity to make comparisons.

Reviewer 4

The reviewer noted that the project consists of three major phases, phase one including initiation and launch, phase two collecting/analyzing data and refining the project, and phase three disseminating lessons learned locally and nationally. A key part of the project approach was to procure the electric vehicles and install the chargers for the two CBOs participating in the project and then train the staff to use them. The reviewer commented that the project set aside CBO personnel time for both training and promotion to the community, and said it was a good approach to make sure that training for the CBO workers and general technical assistance is a prominent part of the project. The reviewer added that the project has a detailed plan for disseminating results to several Clean Cities coalitions directly (via hands-on technical assistance), as well as providing presentations of the results at both local and national venues. In addition, a case study will be valuable to understand lessons learned.

The reviewer stated that it would have been beneficial to understand how the project plans to compare the use of baseline vehicles for each CBO versus the new electric vehicles, and added that there could be an issue of not comparing apples to apples, due to the vehicles' sizes (e.g., the EVs being smaller than the typical vehicles, and not having wheelchair accessibility) and the vehicles' ages (e.g., the EVs being newer than typical vehicles used and not getting a fair comparison of cost of ownership [comparing new EV to new gasoline]).

Reviewer 5

The reviewer commented that a meeting with those that are using the vehicles to better understand their needs from the vehicle could have prevented some of the challenges being seen currently, such as being too low and therefore difficult for seniors to access vehicle, as well as wheelchair accessibility. The reviewer did not understand the reasoning behind having one pilot project in a disadvantaged and underserved area of the community and the other in a part of the community that is not underserved, as opposed to both being in the underserved area.

Question 3: *Project Accomplishments and Progress-Please comment on the project's progress and significant accomplishments to date.*

Reviewer 1

The reviewer commented that the project had tremendous success in procuring the electric vehicles and installing the chargers without significant delays, and added that this is especially impressive due to the pandemic and resulting supply chain issues. As that is such a crucial part of the project, that allowed additional project tasks to be completed. They were able to kick off the project and do virtual training right after the electric vehicle chargers were installed. The reviewer noted that the project has already demonstrated vehicle utilization as well as charging data, and this has put the project on a very good path to being completed and meeting its goals.

Reviewer 2

The reviewer commented that excellent progress has been made towards achieving project goals, and noted that the project has made progress on several key activities:

Five Chevy Bolts have been deployed since Q3 2021, and

Five L2 Chargers have been operational since Q3 2021.

The service was officially launched on Sept 30, 2021 and between Dec 2021 and March 2022, 358 rides have been conducted and 3,629 meals were delivered. Additionally, data collection has commenced.

Reviewer 3

The reviewer remarked that this project is well underway and is already providing lessons learned and valuable data.

Reviewer 4

The reviewer commented that the project faced some delays and changes in operations due to the COVID-19 pandemic; however, the project successfully deployed the vehicles and infrastructure and has begun giving rides and doing meal deliveries.

Reviewer 5

The reviewer remarked that the project milestones and accomplishments were met on time with no noticeable hiccups. The reviewer pointed out that the presenter did not mention the Bolt recall, so it is assumed that these vehicles did not suffer any significant break in service, and noted that the presentation included the first sets of data.

Question 4: *Collaboration and Coordination Among Project Team—Please comment on the level of collaboration within the project team and the degree to which the project team has identified and leveraged the proper connections to achieve its project goals.*

Reviewer 1

The reviewer commented that the project demonstrated significant coordination with project partners in its ability to quickly obtain the electric vehicles, install the chargers, and work with the two CBOs to initiate the project. The reviewer added that the presentation highlighted that the project team is in frequent communication about the status of the project, and they are trying to engage the team to help get feedback on how to improve the project as it proceeds.

Reviewer 2

The reviewer commented that an excellent project team, including the lead recipient (Forth), community partners (Northside Youth & Senior Center and City Seniors, Inc.), industry partners (GM, AmpUp, Ameren, Natural Resources Defense Council), additional community organizations (North Newstead Association and the St. Louis Area Agency on Aging), and the local Clean Cities coalition (St. Louis Regional), has been assembled to carry out this project and provide an appropriate mix of expertise among team members. The reviewer added that collaboration/communication among project partners appears to be appropriate for a project of this scope.

Reviewer 3

The reviewer observed that the project team has regular project calls and updates to the broader community, and noted that they have also presented at conferences and will more broadly distribute a toolkit once development is complete.

Reviewer 4

The reviewer observed that the presentation clearly outlined how the team conducted meetings, check ins and communication, and noted that this project has an impressive list of ten partners.

The presenter stated that the case study and findings will be shared at conferences and through media release and project marketing, and that Forth would be available to assist Clean Cities as needed, but the reviewer noted that it is unclear what happens to the tool kit and case study after the completion of the project.

Reviewer 5

The reviewer remarked on the great set of stakeholders on the team. With the vehicle accessibility oversight/ lessons learned, the reviewer wondered how much of a voice each team member has in the project development and implementation.

Question 5: *Energy Equity and Environmental Justice Project Contribution-Please provide comment on the contribution of this project to energy equity and environmental justice by ensuring the project benefits underserved and overburdened communities and does not cause increased burdens to these communities.*

Reviewer 1

The reviewer commented that, of the two CBOs participating in the project, one is in a location with a significant percentage of the clientele population being low income and/or a minority, while the other is not in an underserved community, but both are supporting elderly populations. The reviewer noted that, in addition to the direct impact on the communities that the project is involved with, the overall lessons learned from the project could lead to other nonprofit groups supporting disadvantaged communities implementing electric vehicles. The reviewer stated that the goal of the project is to demonstrate whether these vehicles are cost-effective and meet the operational requirements of these organizations, and if it is found to be the case, this could lead to cost savings and help these organizations focus more of their resources on their mission. In addition, the use of electric vehicles offer zero tailpipe emissions in the communities where the vehicles are driven.

Reviewer 2

The reviewer remarked that the project has an excellent potential to contribute to energy equity and environmental justice goals by demonstrating how EV fleets can save community-based organizations and social service agencies money and improve service delivery and create a model for deploying EVSE that serves those fleets and can also serve employees and community members. The reviewer observed that the project is providing electric vehicle service in a section of St. Louis with little to no EVSE availability; additionally, the project has significant and active participation from a number of community-based organizations.

Reviewer 3

The reviewer commented that this project is very impactful to an underserved community, it added charging to an area with no access, and provides services to a disadvantage population. The reviewer added that, beyond providing services with no tailpipe emissions, it serves to broaden the exposure to clean transportation technology.

Reviewer 4

The reviewer commented that the average North St. Louis location client is described in the presentation as “low-income African American” in the 65-74 age range, and observed that this program aims directly at this overburdened community with a disadvantaged population. The reviewer added that Meals on Wheels and similar organizations are designed to help the elderly and low income, and those in need, and this project is targeted at those organizations.

Reviewer 5

The reviewer commented that half of the project is in an underserved community, which is great. The reviewer added that consideration should be given to why both fleet pilots were not deployed in the underserved area.

Acronyms and Abbreviations

AFDC	Alternative Fuels Data Center
AFV	Alternative fuel vehicle
AMR	Annual Merit Review
BWI	Baltimore/Washington International Airport
CBO	community-based organizations
CFO	Clean Fuels Ohio
DOE	U.S. Department of Energy
DOTs	Departments of Transportation
EEJ	Energy and environmental justice
EJ	Environmental Justice
EMA	Engine Manufacturers Association
EV	Electric vehicle
EVI	Electric vehicle infrastructure
EVSE	Electric vehicle supply equipment
EZMT	Energy Zones Mapping Tool
GHG	Greenhouse gas
HBCU	Historically Black Colleges and Universities
HD	Heavy-duty
LD	Light-duty
LDV	Light-duty vehicle
LPG	Liquified petroleum gas (propane)
MD	Medium-duty
MUD	Multi-unit dwelling
MWBE's	Minority and women owned business enterprise
NAFA	National Association of Fleet Administrators
NASEO	National Association of State Energy Officials
NEVI	National Electric Vehicle Infrastructure
NREL	National Renewable Energy Laboratory
OEM	Original equipment manufacturer
PAC	Project advisory committee
PERC	Propane Education and Research Council

PHEV	Plug-in hybrid-electric vehicle
PI	Principal investigator
REV	Regional Electric Vehicle
ROI	Return on investment
SCAQMD	South Coast Air Quality Management District
TCO	Total cost of ownership
TI	Technology Integration
TNC	Transportation network company
USPS	United States Postal Service
VTO	Vehicle Technologies Office
WVU	West Virginia University
kW	Kilowatt

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7. 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 VTO Analysis (VAN) subprogram supports the planning and execution of technology, economic, and interdisciplinary analyses to inform and prioritize VTO research portfolio planning, including activities such as research target-setting and benefits estimation. VAN supports vehicle data, modeling and simulation, and integrated and applied analysis activities using the unique capabilities, analytical tools, and expertise resident in the U.S. Department of Energy's (DOE) national laboratory system. These activities explore advancements in vehicles and transportation systems and resulting energy impacts to inform early-stage R&D 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 7-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
van016	Transportation Data Programs	Stacy Davis (Oak Ridge National Laboratory)	7-4	3.75	3.88	3.75	3.38	3.77
van017	Argonne National Laboratory Vehicle Technologies Office (VTO) Analysis Modeling Program	Michael Wang (Argonne National Laboratory)	7-8	3.50	3.63	3.25	3.50	3.53
van018	Light-Duty Vehicle Choice Modeling and Transportation Decarbonization Analysis	Aaron Brooker (National Renewable Energy Laboratory)	7-12	3.75	3.75	3.38	3.38	3.66
van023	Assessing Energy and Cost Impact of Advanced Vehicle Technologies	Ram Vijayagopal (Argonne National Laboratory)	7-16	3.88	3.63	4.00	3.75	3.75
van032	Tracking the Evolution of Electric Vehicles and New Mobility Technology	Joann Zhou (Argonne National Laboratory)	7-20	3.63	3.50	3.00	3.63	3.48
van033	Transportation Macroeconomic Accounting Models: Vision and Non-Light Duty Energy and Greenhouse Gas (GHG) Emissions Accounting Tool (NEAT)	Joann Zhou (Argonne National Laboratory)	7-24	3.88	3.63	3.38	3.63	3.66

van044	Micromobility Screening for City Opportunities Online Tool	Don McKenzie (University of Washington)	7-28	3.50	3.50	2.38	3.38	3.34
van045	Analysis of Electric Heavy-Duty Driving and Infrastructure Requirements Within A Regional Area	Marcus Alexander (EPRI)	7-32	3.13	3.00	3.63	3.00	3.11
van046	EVI-Equity	D-Y Lee (National Renewable Energy Laboratory)	7-36	3.50	3.75	3.38	3.38	3.59
van047	Integrated Modeling and Technoeconomic Assessment of Electric Vehicle Community Charging Hubs	Eleftheria Kontou (University of Illinois)	7-40	3.75	3.63	3.50	3.38	3.61
van048	Heavy-Duty Electric Vehicle Integration and Implementation (HEVII) Tool	William Northrop (University of Minnesota)	7-44	3.75	3.75	4.00	3.38	3.73
Overall Average				**3.64**	**3.60**	**3.42**	**3.43**	**3.57**

Presentation Number: van016
Presentation Title: Transportation Data Programs
Principal Investigator: Stacy Davis, Oak Ridge National Laboratory

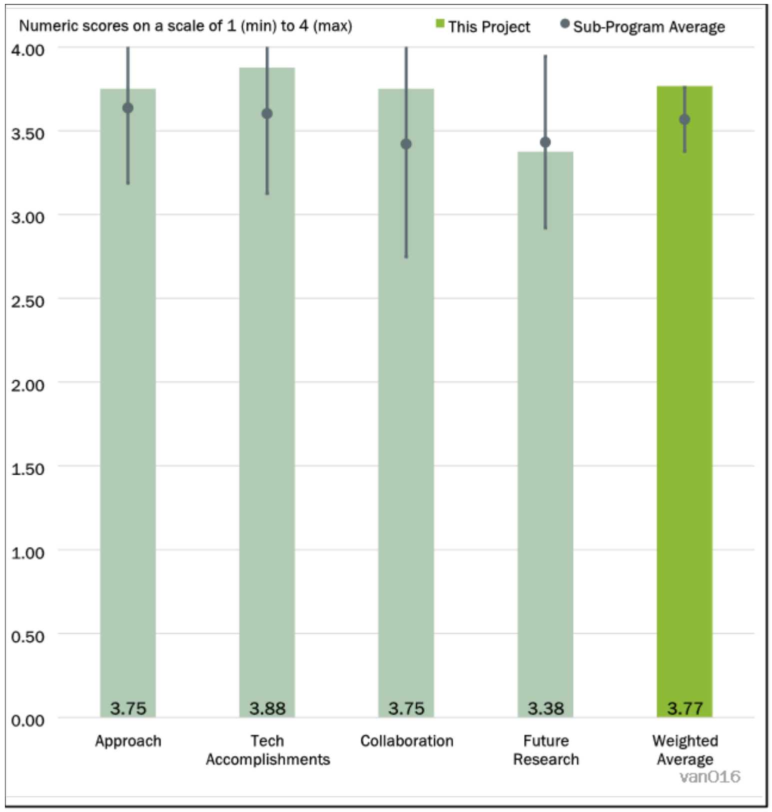

Figure 7-1 - Presentation Number: van016 Presentation Title: Transportation Data Programs Principal Investigator: Stacy Davis, Oak Ridge National Laboratory

Presenter

Stacy Davis, ORNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer declared that the project, including the timeline, is well designed, as it has been for a number of years. Stacy and the team at Oak Ridge National Laboratory (ORNL) have successfully maintained and updated the Transportation Energy Data Book (TEDB), and published Facts of the Week, for many years using a similar approach.

Reviewer 2

The reviewer thought that it would be interesting to understand in the longer term if there are opportunities to streamline or automate the connection of the TEDB and other government related data source (Federal Reserve Economic Data, Energy Information Administration [EIA], U.S. Environmental Protection Agency [EPA], etc.). The reviewer asked if further investment would be worthwhile to create more of a living data ecosystem.

Reviewer 3

The reviewer mentioned that this project is an ongoing data collection and compilation project, using source data from many sources, including other agencies and, when available, surveys. The reviewer added that while some data is dependent on other funding (e.g., for Vehicle Inventory and Use Survey [VIUS] funding), more methods for identifying outdated data to target for additional study are a bit ad hoc and could be more systematized. The reviewer concluded by saying that the process for finding and cleaning the data still seems to be fairly labor-intensive and requires a significant amount of staff time.

Reviewer 4

The reviewer had no specific comments here.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer mentioned that the TEDB has been updated as planned in the approach (PDF and Excel online, updated with current data between editions), and that the Transportation Fact of the Week has been selected, written, and published all year (the reviewer noted receiving the emails). The reviewer added that the team collaborated to update light-duty vehicle (LDV) scrappage rates and help finalize the 2021 VIUS questionnaire, which are not part of regular TEDB or Fact of the Week (FOTW) updates. The reviewer stated that both the TEDB and Fact of the Week appear to maintain a wide audience (50k/year for TEDB, FOTW accounted for half of all VTO site pageviews in 2022), which is great!

Reviewer 2

The reviewer noted that project milestones for the Data Book are generally on schedule (pending some data availability), and that the Facts of the Week were consistently delivered.

Reviewer 3

The reviewer made no specific comments here.

Reviewer 4

The reviewer stated that data science is advancing rapidly, particularly with the integration of artificial intelligence algorithms for data processing. The reviewer said that, based on the merit review presentation, it seems like a lot of the data processing and management methods used for this project are quite manual. The reviewer added that this does contribute to data accessibility in the final product, but that it does not necessarily provide an efficient method for data collection and collation.

Question 3: Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1

The reviewer noted that the project has good collaboration with other labs and projects within the broader VTO portfolio, in both providing data and highlighting other work through the FOTW.

Reviewer 2

The reviewer stated that the ORNL team works closely with the public/private entities that provide data for the TEDB, and with VTO and the national labs for FOTW. The reviewer mentioned that these are key stakeholders for both products.

Reviewer 3

The reviewer declared that it's clear that this team collaborates closely with many other teams in the VTO to ensure that the data required by the overall team is made available in a consistent manner on an annual basis.

Reviewer 4

The reviewer mentioned that the discussion on how collaborations are decided on or not, for expanding the data book, could be improved. The reviewer asked how new data points and partner options are prioritized when funding becomes available. The reviewer additionally asked if it is merely serendipitous, or if the presenter has a list of points to expand and a process to evaluate how to do that.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer mentioned that the future research for this project includes continued updating of the TEDB and publication of the FOTW, in addition to streamlining and adding new data where possible. The reviewer said that this is exactly what users (including VTO) will need—updated data to feed their modeling and analysis efforts.

Reviewer 2

The reviewer stated that the future work focused on continuing to make regular updates, expanding the topics covered (including metrics of transportation access for underserved populations), and using more application programming interface (APIs) from other sources to automate the data collection process. The reviewer thought that the use of APIs will be helpful for streamlining some of the data collection process, especially from sources that are updated frequently. The reviewer added that other scripts could also help with data collection and formatting from other sources that are used consistently but may not have an API.

Reviewer 3

The reviewer noted that it is clear that commercial vehicle, off road applications, and underserved populations are foci for the VTO in the coming years. The reviewer thought that there would also be some value in automating data collection and collation processes more where available.

Reviewer 4

The reviewer was interested in more information on how the presenter prioritizes and decides what information will be included in future versions of the data book. The reviewer asked how the team prioritizes existing and potential data points that could be published.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer stated that the project provides foundational data for many of the other VTO programs through the Data Book, and that it highlights ongoing work through the FOTW.

Reviewer 2

The reviewer noted that this project strongly aligns with the first VTO Analysis objective: Create and maintain a strong foundation of data.

Reviewer 3

The reviewer declared that the TEDB provides a consistent and trustworthy transportation data set for government, commercial, and educational organizations. The reviewer said that the further expansion to include more information about medium-duty (MD)/heavy-duty vehicles (HDVs), off-road applications, and underserved populations will enhance the availability of public data for the study of transportation.

Reviewer 4

The reviewer mentioned that the Data Book is clearly useful to both government agencies as well as academia, industry and the public. The reviewer added that good official data on roadway fleet, travel demand and energy use is vital to many projects and that without this effort it would be scattered across many different sources, or not publicly available.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer noted that the resources are sufficient, and that Stacy and team have a long record of completing this work in a timely fashion.

Reviewer 2

The reviewer stated that the resources are sufficient to support staff to produce the Data Book and FOTW. The reviewer mentioned that it is somewhat unclear how much additional support is necessary to do deeper dives (perhaps in collaboration) with difficult-to-collect data that needs updates and does not get funded through other agencies.

Reviewer 3

The reviewer said that it would be good to see a slight bump in resources to automate a bit more of the data management.

Reviewer 4

The reviewer declared that the presenters noted that funding was a major limitation to expanding the Data Book's expansion and maintenance. The reviewer added that this is one of those projects where this will likely always be true and that the U.S. Department of Transportation/VTO must make a decision on how expansive it needs to be. The reviewer and other colleagues still have issues finding data that they know federal and local agencies collect, which would fit in the Data Book, so the reviewer knows that there would be demand for expansion here.

Presentation Number: van017
Presentation Title: Argonne National Laboratory Vehicle Technologies Office (VTO) Analysis Modeling Program
Principal Investigator: Michael Wang, Argonne National Laboratory

Presenter

Michael Wang, ANL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

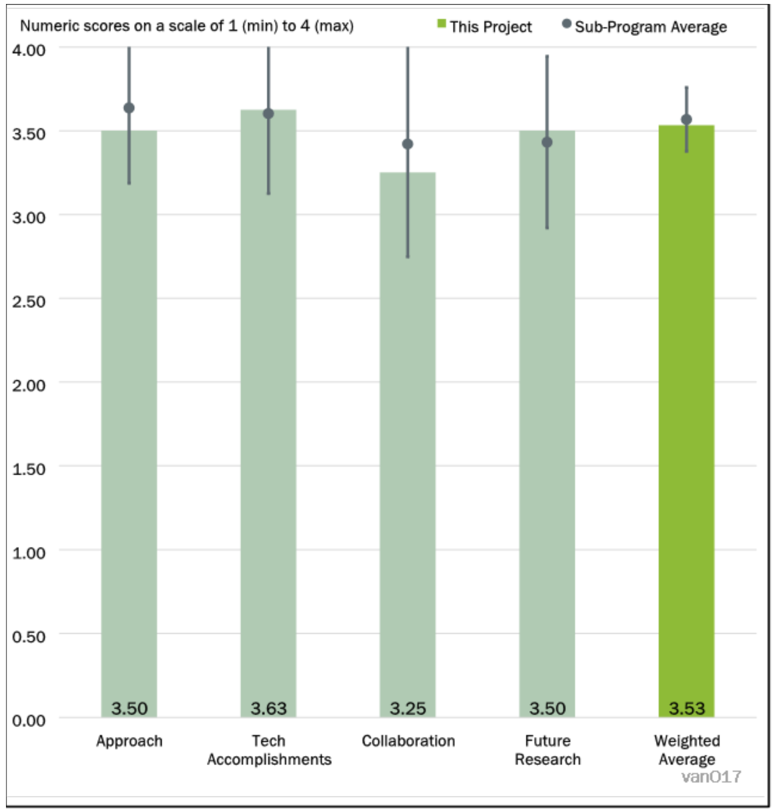

Figure 7-2 - Presentation Number: van017 Presentation Title: Argonne National Laboratory Vehicle Technologies Office (VTO) Analysis Modeling Program Principal Investigator: Michael Wang, Argonne National Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer stated that this project is well structured and that it is addressing the technical barriers as identified.

Reviewer 2

The reviewer mentioned that the model is updated regularly with new information for vehicle information and assumptions about the life cycle impacts of input materials and energy. The reviewer added that the move to have monthly estimates of grid greenhouse gas (GHG) and criteria air pollutant impacts based on energy consumption, rather than generation mix, is good, although some additional time resolution may be important, especially as electric vehicle charging becomes a larger proportion of energy consumption. The reviewer stated that utilizing the Battery Performance and Cost (BatPaC) model as a resource for battery chemistry information is a good strategy, although it's unclear whether there's any additional study to try and assess how different manufacturers select battery materials, and the overall impact that would have on some of the fleet-wide studies at the state or national level. The reviewer thinks that the strategy of not being a grid capacity expansion model to try and predict future emissions is a good approach, and that there are other models (several from the National Renewable Energy Laboratory [NREL] outside of the VTO portfolio that may be helpful if the team wanted to examine future grid emissions scenarios.

Reviewer 3

The reviewer noted that GREET aims to overcome the listed technical barriers: inconsistent data, assumptions, and guidelines; lack of indicators/methodology for evaluating environmental sustainability; need for evaluation of energy/emissions benefits of vehicle/fuel systems. The reviewer added that the approach for this specific project (van017, 2019-2022) helps expand GREET's ability to overcome these barriers, particularly with respect to freight trucks and vehicle electrification. The reviewer said that the data availability and quality issue should be presented in more depth, and that this model is clearly extremely detailed, and there are a large number of assumptions required to impute missing data. The reviewer concludes that the timeline seems to have been reasonably planned, since the milestones have all been either met or are on track.

Reviewer 4

The reviewer declared that a larger discussion on the consistency and transparency aspects of this project would be helpful. The reviewer is still not certain how the team plans to square all the different input life-cycle analysis (LCA) components with each other in GREET.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer mentioned that the regular updates of the model (yearly) are on schedule, and that the model has been expanded to cover MD/HDV.

Reviewer 2

The reviewer stated that the project appears to be on time and on schedule to deliver as planned. The reviewer added that the remaining challenges are well defined.

Reviewer 3

The reviewer made no specific comments.

Reviewer 4

The reviewer said that expanding GREET to include MD/HDVs (and to compare their well-to-wheel emissions) was successful, with significant detail, but the final result metrics are reported on a per-mile basis. The reviewer added that a per-ton-mile metric would more accurately show emissions per unit of work, and that battery electric vehicles (BEVs) (particularly for Class 8 long haul) will likely produce less work (payload-ton-movement) per mile than the equivalent internal combustion engine (ICE). The reviewer also questioned what the assumed battery size was. The reviewer mentioned that the cradle-to-grave analysis and annual GREET model publication are both either completed or on-track for completion.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer stated that the project makes good use of collaborations with other labs, universities, and trade organizations to source information for the model.

Reviewer 2

The reviewer said that there was close collaboration with other VTO teams, government organizations, academic institutions and industry groups.

Reviewer 3

The reviewer noted that the collaboration was excellent for the light-duty vehicle and grid work, but that there was not much collaboration on the MD/HDV side of the analysis.

Reviewer 4

The reviewer recommended a larger discussion about verification of appropriate, and consistency of provided input data, and how similarity is verified. The reviewer noted that the team works with, or uses data from, many different actors here and it identifies consistency and quality of this data as a problem. The reviewer suggested going further in putting forward a plan to address this.

*Question 4: **Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?***

Reviewer 1

The reviewer declared that future work appears to be achievable and relevant to further overcoming the stated barriers.

Reviewer 2

The reviewer noted a clear plan for future work.

Reviewer 3

The reviewer remarked that the proposed work includes continuing to update existing models, and expanding the MD/HDV models. The reviewer suggested considering including some other non-highway (but still on-ground) vehicles if that aligns with other VTO priorities. The reviewer didn't know that this is the best program to address techno-economic issues (it was listed as a "challenge"). The reviewer added that including other pollutants besides CAP and GHG would be helpful when assessing the equity considerations associated with different transportation technologies and their production.

Reviewer 4

The reviewer said that GREET is a very complex project and perfecting it will always be limited by resources. The reviewer declared that while the presenters explain what they plan to do next, this type of continuous project would benefit from a larger discussion on how improvements and fixes are identified and prioritized.

*Question 5: **Relevance: Does the project support the overall VTO subprogram objectives?***

Reviewer 1

The reviewer said that the project provides a consistent resource in evaluating the GHG emissions and other key pollutant and resource consumption impacts of different VTO programs.

Reviewer 2

The reviewer mentioned that the project directly supports the VTO Analysis Program goals by supporting quantitative assessment of vehicle and mobility technology impacts.

Reviewer 3

The reviewer noted that it's relevant across subprograms.

Reviewer 4

The reviewer noted that this is a vital tool, with few publicly accessible or modular alternatives. The reviewer added that the improvements can be expected to greatly improve this tool.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated that funding levels were sufficient for maintaining and continuing to expand the current model scope.

Reviewer 2

The reviewer noted that the resources seemed sufficient.

Reviewer 3

The reviewer said that the resources appear to be sufficient.

Reviewer 4

The reviewer made no specific comment.

Presentation Number: van018
Presentation Title: Light-Duty Vehicle Choice Modeling and Transportation Decarbonization Analysis
Principal Investigator: Aaron Brooker, National Renewable Energy Laboratory

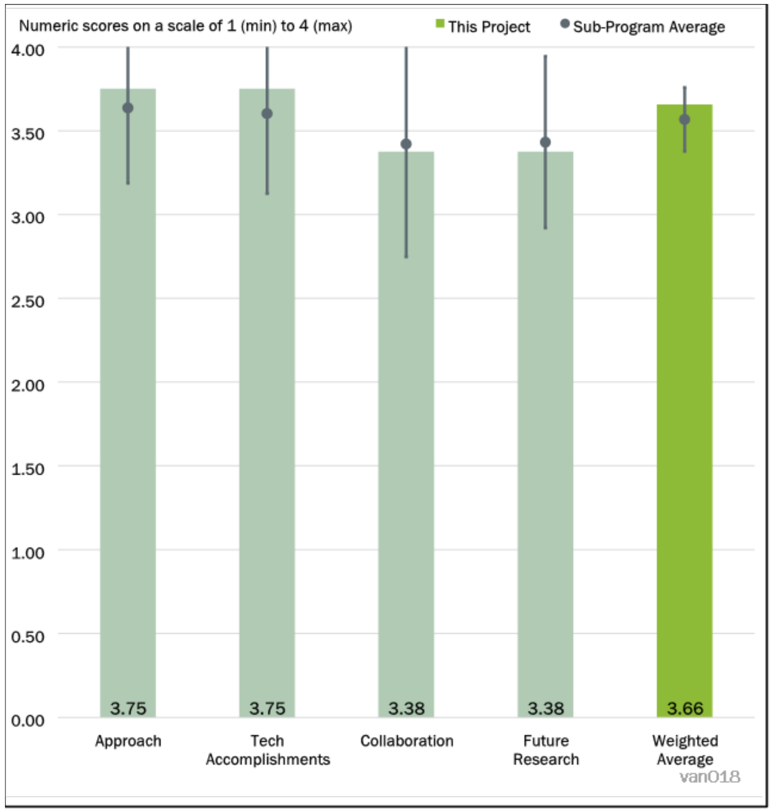

Figure 7-3 - Presentation Number: van018 Presentation Title: Light-Duty Vehicle Choice Modeling and Transportation Decarbonization Analysis Principal Investigator: Aaron Brooker, National Renewable Energy Laboratory

Presenter

Aaron Brooker, NREL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer declared that the project is well designed and the timeline is reasonable (the team has already met most of the planned milestones). The reviewer added that the work so far—implementing decarbonization technology pathways in Automotive Deployment Options Projection Tool (ADOPT)—directly addresses the stated barrier, specifically an exploration of how VTO’s decarbonization-related technologies might play out in the market. The reviewer added that using ADOPT (as opposed to a different or new modeling framework) is reasonable given the extensive validation against real-world market outcomes.

Reviewer 2

The reviewer said that the approach seemed reasonable.

Reviewer 3

The reviewer made no specific comments.

Reviewer 4

The reviewer stated that the project has incorporated other recent policy changes and targets to provide insight into potential impacts of these programs. The reviewer added that technology models informed by specific programs (e.g., batteries and fuel cells) are a positive step, although the reviewer was not sure about the price vs. cost assumptions, especially as original equipment manufacturers (OEMs) are playing a more active role in funding the construction of manufacturing facilities for these inputs (batteries especially), and may be able to negotiate better terms than a standard 1.5x fixed profit margin). The reviewer suggested that it may also be worth discussing some additional negative feedback loops on battery size: as the range continues to increase, there are also negative implications because of available battery materials, and a market-wide shift to even longer-range vehicles may exacerbate material costs beyond the more temporary price fluctuations that we've seen recently.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer stated that the project continues to make routine updates based on vehicle projections and inputs like fuel/material costs, and has successfully implemented multiple incentive policy scenarios. The reviewer added that the tool is able to estimate sales by household income, although other Diversity, Equity, Inclusion and Accessibility (DEIA) metrics are lacking.

Reviewer 2

The reviewer said that the team has accomplished a number of model improvements, both methodological (changing LDV market offerings by income bin) as well as policy-related (new corporate average fuel economy [CAFÉ], new pending BEV incentives). The reviewer specified that the former is a great way to further align the model output with BEV market reality (BEV manufacturer's suggested retail price is ~40% higher than conventional ICEs, and therefore are primarily purchased by those in higher income brackets). The reviewer added that the updated key assumptions seem reasonable. The reviewer had a hard time believing sub-¢0.20 electricity prices through 2050, particularly in scenarios where BEVs take large portions of the LDV market and lower-income and other non-single-family-home-owning folks have EVs and have to charge publicly. The reviewer understood that this is likely pulled directly from EIA's Annual Energy Outlook (AEO), but suggested that it would be helpful to explore the sensitivity of the model to electricity price. The reviewer concluded that overall, it looks like the team explored a wide range of scenarios, which is great!

Reviewer 3

The reviewer mentioned that the approach appears to be robust to analyze future scenarios. The reviewer added that final reports could likely use a little more explanation as to how various scenarios are selected.

Reviewer 4

The reviewer made no specific comments.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said the day-to-day project work is led by the NREL team, although other program managers/offices provide feedback regarding cost and performance targets of electrification technologies.

Reviewer 2

The reviewer stated that the work is all done by NREL, although there was a significant amount of DOE inter-office coordination and collaboration required to develop and agree on the modeling assumptions.

Reviewer 3

The reviewer noted that there appears to be good coordination within DOE, but that there may be a bit more opportunity for collaboration with external organizations/educational institutions, particularly on the development and rationale of scenario options.

Reviewer 4

The reviewer made no specific comments.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer stated that the future work is clearly defined and aligns with both VAN and wider VTO goals, including the Justice40 initiative. The reviewer added that the principal investigator (PI) also included regular annual updates in the proposed future research, which will enable ADOPT to stay up-to-date with the latest market developments.

Reviewer 2

The reviewer said that the proposed work for continuing/updating existing model capabilities is on track, and did not think there are any "missing" technologies at the passenger vehicle level that are missing from the technology basket; however, the plan for expanding the DEIA metrics is a bit lacking. The reviewer asked if there was any geospatial consideration within the model. The reviewer added that while there was agreement between the ADOPT predictions and actual vehicle sales by income, ADOPT tended to over-estimate sales in the highest income bracket, while states with large electric vehicle (EV) markets have made some efforts at income-based incentives for EV adoption (California being the largest). The reviewer asked what other metrics included in the model already have DEIA implications.

Reviewer 3

The reviewer noted that the proposed future research is aligned with other VTO light vehicle initiatives, with gained focus on DEIA expansion. It was not clear to the reviewer if there is any intent to be able to do similar scenario evaluation with more commercial applications in the MD/HDV space and off road.

Reviewer 4

The reviewer made no specific comments.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said that estimating trends in the passenger vehicle market is important, and that the model has done a good job interfacing with other programs to show how technology improvement in the DOE portfolio can have an impact.

Reviewer 2

The reviewer declared that the project directly supports all of the VAN goals, particularly Assist VTO in prioritizing technology investments and inform research portfolio planning; and Support quantitative assessment of vehicle and mobility technology impacts.

Reviewer 3

The reviewer mentioned that the subprogram objectives are supported.

Reviewer 4

The reviewer stated that this project does seem more single purpose than the other projects.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated that the project resources are sufficient for maintaining a team to conduct routine updates (although potentially integrating more data through the EIA API for AEO updates may speed up the process and allow more time for implementing policy considerations/other new technologies/DEIA considerations).

Reviewer 2

The reviewer said that NREL, and specifically Aaron Brooker, have been working on developing and maintaining ADOPT for a long time now. The reviewer added that they appear to be fully capable of achieving the stated milestones (as they have done so far).

Reviewer 3

The reviewer noted that the resources appear to be sufficient, and that the project appears to be on-time, on-budget.

Reviewer 4

The reviewer made no specific comments.

Presentation Number: van023
Presentation Title: Assessing Energy and Cost Impact of Advanced Vehicle Technologies
Principal Investigator: Ram Vijayagopal, Argonne National Laboratory

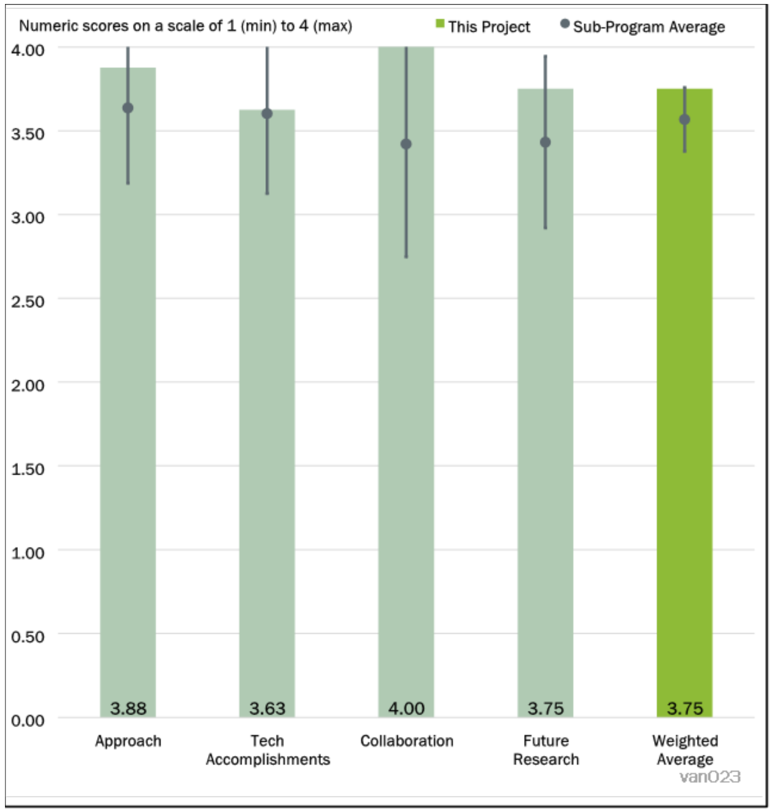

Figure 7-4 - Presentation Number: van023 Presentation Title: Assessing Energy and Cost Impact of Advanced Vehicle Technologies Principal Investigator: Ram Vijayagopal, Argonne National Laboratory

Presenter

Ram Vijayagopal, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer mentioned that this project specifically addresses a key VTO barrier: determining whether the research portfolio will achieve the broader goals of the office. The reviewer noted that it addresses this barrier by implementing the new technology targets (cost and performance) into Autonomie to determine impacts on vehicle operations (energy, total cost of ownership (TCO), price). The reviewer concluded that the project is well-defined and the timeline, while packed full, will likely be met based on progress to date.

Reviewer 2

The reviewer stated that the data management and use of high performance computing (HPC) for the Autonomie model is excellent, especially when there are so many possible technical pathways to vehicles with similar performance characteristics. The reviewer added that the use of spreadsheets for the BEAN tool makes sense, especially to serve as an easily-accessible solution, however there may need to be some additional barriers or warnings within such a tool, especially if users are able to input parameter values that are well outside of the range of inputs included in the post-processed dataset.

Reviewer 3

The reviewer declared that the approach appears to be sound with respect to how the tools evaluate cost and technology implication, but that at the same time the scenarios evaluated and presented rely on some assumptions that may not hold. The reviewer pointed to, for example, the following assumptions: 1) powertrain cost reductions for battery electric vehicles are passed down directly from the OEM to the consumer, 2) powertrain cost reductions are not offset by the addition of further vehicle content (connected, advanced driver-assistance system (ADAS), infotainment, comfort/trim, etc...), and 3) consumer vehicle purchase decisions are more economic than emotional. The reviewer concluded that while these types of externalities are impossible to fully capture in any analysis, with final reporting they should be addressed more explicitly than in the AMR presentation where there potentially was no time.

Reviewer 4

The reviewer made no specific comments.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer stated that the passenger vehicle market and technology combinations continue to be well represented, and the number of MD/HDVs included has been greatly expanded. The reviewer added that the BEAN model was released to provide easier access to compiled results, although the spreadsheet could be refined to provide a bit more user guidance when values entered are outside of the modeled input values.

Reviewer 2

The reviewer said that the team completed a report for all LD/MD/HDV classes and deployed the new BEAN tool to enable stakeholders to adjust assumptions and develop their own scenarios. The reviewer noted that the former is a large task on its own, and that the latter is a significant contribution to making the overall analysis more transparent. The reviewer recommended that the team should strongly consider using a different electricity cost for EVs (sub-¢0.20 /kWh through 2050 seems optimistic), as this has a significant impact on the TCO and payback calculations. The reviewer emphasized that the team did an excellent job making this entire framework more accessible and “open-source”. The reviewer said that the timing of the model updates is a little ambiguous. The reviewer explained that the team significantly expanded the number of vehicle and powertrain permutations that are being modeled, but that it wasn’t clear that this was a VAN023 accomplishment. The reviewer added that the only comparison is to 2016, which long predates the project. The reviewer asked if the expansion from 2,600 to12,000, and from 5 LDV classes to 30 LD/MD/HDV classes was completed as part of this project or before this project.

Reviewer 3

The reviewer noted that the technical approach is sound.

Reviewer 4

The reviewer made no specific comments.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer said that the project team is well-integrated with other teams for gathering the vehicle efficiency technology cost/performance data, and communicates with relevant stakeholders to ensure that the most relevant metrics are included as output metrics within public-facing tools.

Reviewer 2

The reviewer highlighted that the team works with a wide range of stakeholders to generate the input assumptions for this modeling work. The reviewer acknowledged that it isn't easy to corral and synthesize all of the recommendations from the diverse crowd, and emphasized the great work done.

Reviewer 3

The reviewer noted the excellent collaboration with public and private partners.

Reviewer 4

The reviewer declared that the presenters gave a thorough discussion of what they got from collaborators and how they got potential user input on how the product should be used.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer stated that the data management and HPC framework is scalable for integrating the additional technologies and vehicle classes. The reviewer added that the BEAN tool can probably be further refined as a spreadsheet-based tool with some "guardrails" to inform users when they are departing from the space modeled in the post-processed data.

Reviewer 2

The reviewer noted that the focus on proposed future research is aligned with the commercial vehicle markets where there are more frequent "rational" customer vehicle decisions based on TCO and application suitability.

Reviewer 3

The reviewer made no specific comments.

Reviewer 4

The reviewer said that future research is wide-ranging and that the team should focus on refining its current on-road model, which will require significant effort just to maintain and keep up to date.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer stated that the project provides useful information about the cost of technologies in the VTO portfolio, and that the Autonomie model is a key tool that uses good data management techniques to rapidly assess the full design space for fuel economy technologies in the passenger vehicle space, with increasing resources for other vehicle categories.

Reviewer 2

The reviewer said that this is specifically relevant to all of VAN's goals: Assist VTO in prioritizing technology investments and inform research portfolio planning; Support quantitative assessment of vehicle and mobility technology impacts; Provide insight into transportation and energy use problems for a broad range of internal and external stakeholders.

Reviewer 3

The reviewer noted that this project provides a methodology to evaluate the potential impact of all other development programs.

Reviewer 4

The reviewer declared that this project should contribute to cost parity work which is vital to long term projects and decision making.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said that resources are sufficient to complete the outlined scope of work.

Reviewer 2

The reviewer stated that the ANL team has many years of success developing, maintaining, and improving this modeling framework.

Reviewer 3

The reviewer noted that the project appears to be on time and on budget.

Reviewer 4

The reviewer made no specific comments.

Presentation Number: van032
Presentation Title: Tracking the Evolution of Electric Vehicles and New Mobility Technology
Principal Investigator: Joann Zhou, Argonne National Laboratory

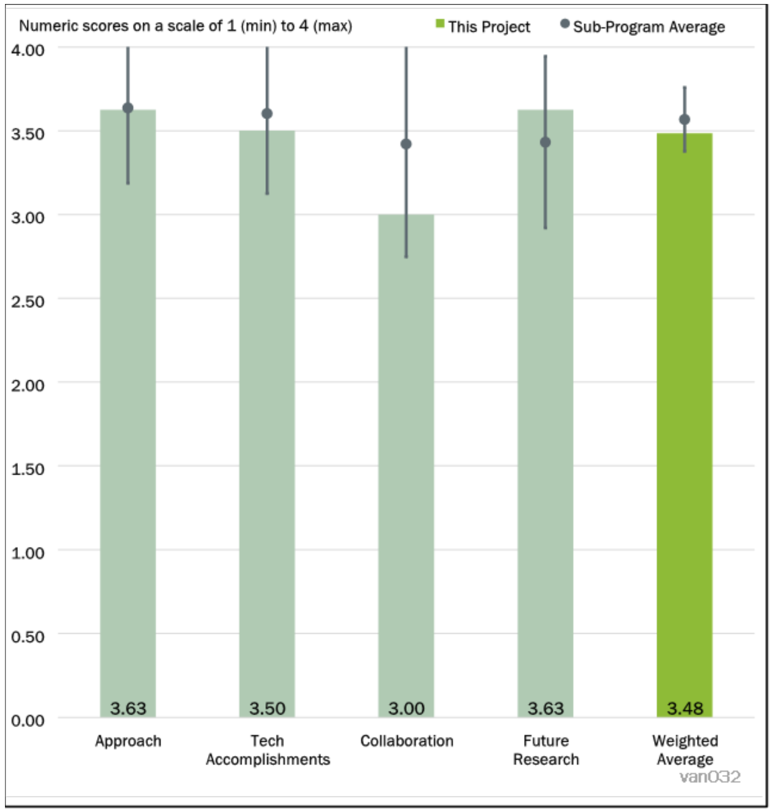

Figure 7-5 - Presentation Number: van032Presentation Title: Tracking the Evolution of Electric Vehicles and New Mobility Technology Principal Investigator: Joann Zhou, Argonne National Laboratory

Presenter

Joann Zhou, ANL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer stated that the project has expanded the scope to include commercial sales data on EVs, information about the supply chain for electrified vehicle technologies, and has begun to provide analysis for geospatial and equity-based analysis of mobility technology adoption. The reviewer added that while the data format does periodically change over time, any additional post-processing automation would be helpful for cleaning and compiling the data.

Reviewer 2

The reviewer noted that this project aims to address data-related barriers, particularly related to vehicle electrification but also including emerging and advanced mobility, while also addressing what appears to be VTO’s need for ad-hoc analyses to answer internal/external inquiries. The reviewer added that the approach is to append new data to ANL’s historical dataset (back to 1999), and then to leverage the growing dataset for further analysis like tracking trends or estimating energy or emissions impacts. The reviewer mentioned that this is reasonable considering the wide breadth of information collection and analysis the project team aims to complete. The reviewer stated that it would have been helpful if the team included the process for selecting which ad-hoc analyses to complete for VTO. The reviewer acknowledged that these can’t be known ahead of time, but asked how the specific reports or analyses were selected. The reviewer emphasized that since this is a project specifically focused on data, the summary presentation should clearly include the data sources as part of the approach, even just a single quick slide, i.e., “Sales: Wards Intelligence; Stocks: Experian Automotive; vehicle-miles traveled /vehicle: IHS Polk odometer records; Vehicle specs: OEM fact sheets.”

Reviewer 3

The reviewer mentioned that there is value to the data being collected and the analysis being completed. The reviewer added that it is not clear how the various vehicle technology office data collection initiatives are integrated.

Reviewer 4

The reviewer made no specific comments.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer said that this project makes use of existing data sources like sales data from Wards, and that data visualization has expanded since previous iterations with the inclusion of Sankey diagrams and geospatial analyses. The reviewer mentioned that it is a bit less clear whether the data used in the figures is available or compiled to be easily downloaded.

Reviewer 2

The reviewer mentioned that the team appears to have successfully completed monthly data updates and annual reports as planned, along with a few standalone analyses/papers from the resulting findings, and that there are lots of interesting things to pick through. The reviewer recommended that the team provide a range of results for those assumptions that are least vetted and most important. The reviewer asked the following questions: How does ANL estimate sales-weighted range when Ward’s doesn’t include any detail on the trim level of Tesla vehicles and when there is no way to know what share of Model 3, Y, S, or X vehicles were Standard versus Long range? What annual mileage was assumed for BEVs for the gasoline displacement analysis? The reviewer clarified that, regardless of agreements/disagreements with the assumption shown in Figure 1 of the ANL/ESD-21/2 report, it is a key unknown, and should therefore be explicitly stated on freestanding graphics (e.g., “Assumes longer range (250 mi+) BEVs travel about the same mileage as conventional vehicles in a given year”) so that the audience knows this is a potential caveat. The reviewer added that Ward’s is very protective of its data, and asked if ANL actually distributes Ward’s make/model sales to the public. If not, the reviewer recommended that this should be made clear in the slides as well.

Reviewer 3

The reviewer stated that there is still room for improvement on data visualization and “so what” explanations.

Reviewer 4

The reviewer made no specific comments.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer stated that the team has partners at Wards for regular sales data updates, and with city agencies working with mobility data. The reviewer added that some additional collaboration may help to gather more information about vehicle (fast) charging characteristics.

Reviewer 2

The reviewer mentioned that the team collaborates as needed to ensure data is collected in a timely fashion, but that it isn't clear that other non-DOE/lab experts were consulted for review of the analysis reports, "Assessment of Light-Duty Plug-In Electric Vehicles in the United States, 2010–2020," and "Regionally-Resolved Emissions from Electric Vehicles in the United States." The reviewer added that these should be reviewed by outside experts who have already thought through many of these assumptions.

Reviewer 3

The reviewer noted that the presenters provided information on their plans to gather more information from users. The reviewer asked what has been done up till now.

Reviewer 4

The reviewer said that this project and the TEDB seem to have similar objectives. The reviewer noted that it is not clear why these are separate projects with separate investigators. It seemed to the reviewer that there are similarities in the purpose and the execution. The reviewer added that, as with that project, it seems like this project could benefit from automation in data collection, analysis and management.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer said that the proposed future work is basically to continue current work of collecting data, completing monthly/annual reports, and publishing updated analyses based on the latest data. The reviewer added that this is reasonable, and that hopefully it will not require as much effort now that the entire data pipeline and analysis process has been developed and demonstrated.

Reviewer 2

The reviewer noted that future research tracts appear to be reasonable.

Reviewer 3

The reviewer made no specific comments.

Reviewer 4

The reviewer mentioned that the continued work in micromobility trip analysis is well aligned with broader goals around DEI. The reviewer suggested that, on the technical side, the team might consider collecting data on the fast-charging capabilities and protocols for different passenger EVs (https://insideevs.com/news/514857/mic-tesla-model3-srp-charging/) and as it becomes available, MD/HD EVs.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer noted that the project provides key foundational datasets for electric vehicle adoption rates and market parameters, and that it has begun to collect and analyze publicly available micromobility data from different cities.

Reviewer 2

The reviewer stated that yes, this project clearly supports the first VTO Analysis Program objective of creating and maintaining a strong foundation of data.

Reviewer 3

The reviewer mentioned that this project is relevant to multiple subprogram objectives.

Reviewer 4

The reviewer made no specific comments.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated that the resources are sufficient to support staff to compile related data and conduct some analysis on micromobility access.

Reviewer 2

The reviewer noted that the resources seem to have been sufficient for this effort of standing up the pipeline and analysis processes and completing the work.

Reviewer 3

The reviewer said that the project appears to be on time and on budget.

Reviewer 4

The reviewer made no specific 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

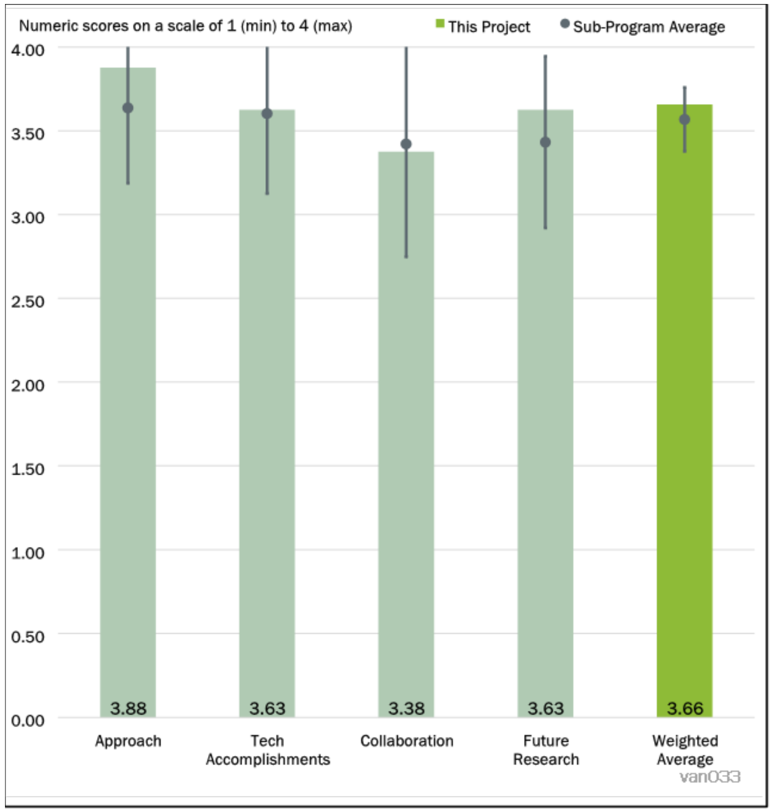

Figure 7-6 - Presentation Number: van033 Presentation Title: Transportation Macroeconomic Accounting Models: Vision and Non-Light Duty Energy and Greenhouse Gas (GHG) Emissions Accounting Tool (NEAT) Principal Investigator: Joann Zhou, Argonne National Laboratory

Presenter

Joann Zhou, ANL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer noted that the project has continued to update the technologies considered, including more heavy-duty vehicles. The reviewer added that the partnerships with other projects with relevant data on electricity and vehicle emissions are incorporated. The reviewer mentioned that the geospatial analysis includes large metro vs. other areas, which is important for providing future insight into the disparities in low-carbon transportation systems.

Reviewer 2

The reviewer stated that the approach is to update, maintain, and apply ANL's VISION/NEAT modeling framework to evaluate environmental sustainability, energy benefits, and emissions benefits of vehicle/fuel systems. The reviewer added that this requires overcoming—or even just working with—inconsistent data, assumptions, and guidelines, given the realities of the available datasets, stakeholders, and policies. The reviewer noted that a key piece of the approach is to calibrate the models to EIA AEO projections, thereby ensuring top-line consistency with official U.S. government transportation energy projections. The reviewer declared that to bring in emissions, the team planned to used Cambium and GREET. The reviewer concluded that this is a great approach using the best of existing (and often VTO-funded) data and models to feed a model that estimates energy/emissions.

Reviewer 3

The reviewer mentioned that the model improvements and scenario evaluations are clear and concise. The reviewer suggested that it would be nice if the conclusions from the scenarios evaluated to date were presented a little more clearly in order to be consumable by a broader audience.

Reviewer 4

The reviewer made no specific comments.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer stated that the project has incorporated more geospatially-resolved data, which is helpful for considering different policy scenarios. The reviewer added that updates for both light- and heavy-duty vehicles have been incorporated.

Reviewer 2

The reviewer stated that this is the first level of evaluation in the VTO analysis program currently capable of including off-road applications.

Reviewer 3

The reviewer made no specific comments.

Reviewer 4

The reviewer declared that the team has successfully achieved its 4 objectives although there were no specific milestones listed: annual VISION/NEAT update, enhancing MD/HDV modeling, LDV upsizing, and regional EV emissions analysis. The reviewer noted that an additional Class 7/8 segment was added to the MD/HDV component to simplify application of EPA/ National Highway Traffic Safety Administration regulations and calibration to the AEO, which is great both for the modelers (likely saves time) and for the results, which now better represent the medium/heavy truck market. The reviewer added that the team completed an analysis of alternative LDV upsizing scenarios, but that it wasn't clear why the team used AEO2020 as the baseline for the analysis, as the last historical year for AEO2020 vehicle attributes was 2017 (stocks: 2018). The reviewer noted that this renders the entire effort out of date and nearly irrelevant given the large changes in the market and in policy (e.g., CAFE). The reviewer explained that AEO2022 may have been "too late" (February 2022), but that AEO2021 (February 2021) was certainly released with enough time for inclusion. The reviewer added that while the team clearly stated this was a scenario analysis, it wasn't clear why they would include scenarios that are implausible. The reviewer stated that those shown on Slide 8 are highly unlikely futures. The reviewer said they assume that manufacturers will migrate a large number of their offerings from unibody (CUVs) to body-on-frame (SUVs), even though consumers clearly prefer unibodies (hence the small share of SUVs which only include body-on-frame in the historical data and future projections). The reviewer clarified that perhaps the other scenarios are plausible, but that the team should have left out any that just don't make sense. The reviewer suggested that it would be good, in the future, to ask EIA to review anything that uses AEO data and projections. The reviewer recommended that the team should more clearly state whether the model was updated or not (language in Slide 6 just says "Models are annually updated, calibrated and released to users").

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer stated that this project leverages other data from projects at ANL and NREL to provide insight into vehicle-level and grid-level emissions and energy consumption.

Reviewer 2

The reviewer noted excellent collaboration within the team, and that it wasn't clear if there is significant collaboration outside of the national labs/DOE VTO.

Reviewer 3

The reviewer would like more information on collaboration, particularly with users (government, academia, etc.) and data sources. The reviewer asked how the team makes certain that users know how to properly use the model to create useful and correct results, and what happens when a bug is reported.

Reviewer 4

The reviewer noted that the team collaborated with NREL, which has expertise in MD/HDV modeling, and ORNL, which has access to detailed data and the capability to analyze it. The reviewer suggested that the team should consider checking in with EIA at some point in the process, since VISION is an Excel representation of NEMS TRAN components and EIA can let them know what has changed since the previous AEO.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer stated that the inclusion of off-road technologies is important as on-road vehicles are beginning to have clearer paths towards decarbonization. The reviewer suggested considering adding ammonia as a potential fuel (or as a hydrogen carrier in pipelines/other shipping), and perhaps some synfuel options for jet fuels.

Reviewer 2

The reviewer said that proposed future research is clearly defined as continuing to update VISION/NEAT and estimating regional emissions while investigating off-road technologies and energy equity. The reviewer added that off-road vehicle data is very limited, so it may be more useful to continue refining VISION/NEAT.

Reviewer 3

The reviewer asked how off-road equipment will be categorized and how potential for decarbonization will be evaluated.

Reviewer 4

The reviewer mentioned that the presenters gave a clear goal and plan to address the issue of regionalism in EV effects, and that this is a clear problem that has been identified by many actors.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer said that the project provides a key tool for assessing the impacts of different vehicle adoption patterns, and that it is expanding to include more geospatial resolution, which is a critical piece of information for place-based interventions and improvements in transportation equity.

Reviewer 2

The reviewer stated that this project is relevant to all of the VTO Analysis Program goals and objectives (data, modeling, analysis/insight).

Reviewer 3

The reviewer mentioned that this project supports the subprogram objectives.

Reviewer 4

The reviewer declared that both products are important, not only for government and regulator work, but also for academia and NGOs. The reviewer added that keeping these tools public allows for more effective public engagement on agency actions and that, therefore, these improvements can be expected to deliver improvements to both direct agency work and final outcomes.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated that the project resources are sufficient for updating the existing model and for beginning to expand the technologies included, although the pace at which new off-road technologies are going to be added to the model may justify additional funding given the diversity of technologies and fuels.

Reviewer 2

The reviewer mentioned that the resources seem reasonable.

Reviewer 3

The reviewer noted that the project appears to be on time and on budget.

Reviewer 4

The reviewer made no specific comments.

Presentation Number: van044
Presentation Title: Micromobility Screening for City Opportunities Online Tool
Principal Investigator: Don McKenzie, University of Washington

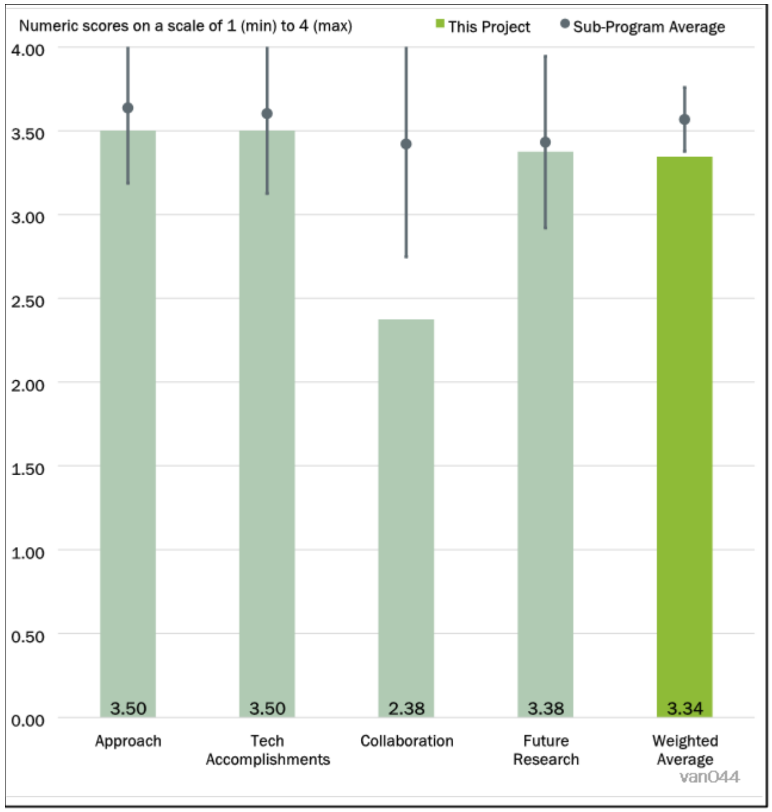

Figure 7-7 - Presentation Number: van044 Presentation Title: Micromobility Screening for City Opportunities Online Tool Principal Investigator: Don McKenzie, University of Washington

Presenter

Don McKenzie, University of Washington

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer stated that the survey was designed and fielded as part of the initial scope of work, and has been incorporated into a choice model. The reviewer added that some barriers remain related to the trip destination generation, and that some approaches for addressing this challenge were included, although one (additional computing power) may require additional resources.

Reviewer 2

The reviewer mentioned that this work intends to expand VTO Analysis Program’s mobility system analysis and modeling capabilities, specifically aiming to investigate and even enhance the cost-effectiveness and energy productivity of micromobility systems by building a new tool. The reviewer added that it directly addresses a key question from the 2020 VAN annual report: “Which vehicle use domains offer the potential to provide clean mobility benefits and at a reasonable cost to both businesses and the consumer? In which applications can specific new technologies make the greatest impact?”. The reviewer noted that the tool’s design—population synthesis, trip/tour generation, mode choice, and calculation of the resulting impacts on demand, energy productivity, and accessibility—should make substantial progress toward understanding how clean and affordable micromobility is. The reviewer concluded that the design is reasonable and that the timeline is feasible.

Reviewer 3

The reviewer noted that the approach is sound, but that it was not clear how remaining challenges and barriers would be overcome (particularly computational complexity).

Reviewer 4

The reviewer made no specific comments.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer stated that the project is ambitious in the number and diversity of tasks and public-facing outputs as part of the scope of work.

Reviewer 2

The reviewer noted that the team has completed a large portion of the model build and assembly as well as input data collection and processing. The reviewer added that literature review and data inventory were each thorough and appear to have provided valuable information to direct the model development (and geographic focus for validation). The reviewer declared that the SP/RP survey was completed with a reasonable response rate, although it wasn't clear whether it is representative of the population. The reviewer asked if most MTurk users are tech-savvy, and therefore more likely to use app-based micromobility in the first place.

Reviewer 3

The reviewer made no specific comments.

Reviewer 4

The reviewer declared that only achieved project milestones were shown in the AMR presentation, and that it was unclear exactly what milestones remain.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer noted that there are no partners on this project.

Reviewer 2

The reviewer stated that this is a single-entity project, which makes sense given the funding level. The reviewer added that the PI mentioned that there had been previous work with Toyota, but that it is unclear whether they are involved in any capacity in the current work. The reviewer said that there may be areas of synergy (e.g., processing micromobility trip data with other projects as they expand the cities studied has overlap with some of the work from VAN032), and partnerships with some of the cities studied, or transit organizations/nonprofits in these cities that could help with disseminating the research.

Reviewer 3

The reviewer declared that, though the University of Washington is the only organization on this project, it seems like an opportunity is being missed to coordinate with commercial, nonprofit, and other entities in the micromobility space to understand the requirements for this kind of market identification and some of the pitfalls that they have encountered. The reviewer added that a few interviews facilitated by DOE project sponsors or at conferences could go a long way to inform the presentation and visualization of data, and to identify potential biases and artifacts in the attribute data.

Reviewer 4

The reviewer commented that more information is needed on how to determine that this product is useful to users. The reviewer asked how the team is getting feedback or ensuring that the tool is being designed for end user needs.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer mentioned that the proposed work for the remainder of this project focuses on refining previous modeling work, calculating energy productivity of different modes, and displaying accessibility metrics to be published as part of a web tool. The reviewer added that some additional computational challenges may remain for calculating routes between destinations and expanding it to other cities in the future.

Reviewer 2

The reviewer commented that future work within the project is as expected, and that the proposed future work would be great to further refine the methodology and get at some of the heterogeneity.

Reviewer 3

The reviewer noted that there appears to be some infrastructure related factors that have been considered, such as whether or not there is a bike lane, but that, from a DEI perspective, there may be more infrastructure considerations for some cities and neighborhoods such as: sidewalk availability; what the condition of the road/sidewalk is; if roads have shoulders; if all roadways are paved. The reviewer added that population density may not be fully representative of required distances of travel for shopping, groceries/schools. The reviewer asked if this has been taken into account.

Reviewer 4

The reviewer made no specific comments.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer stated that the project has compiled a substantial amount of trip data from different cities that requires mobility companies to provide it, and have used it to model trips in conjunction with user preference surveys. The reviewer added that the goal of the project is to provide quickly-returned analyses for other cities considering mobility technologies insight into the types of services and infrastructure necessary to support these services and expand access to low-carbon transportation. The reviewer noted that this can be especially helpful for providing additional access in low-resource communities that are a focus of the Justice 40 Initiative.

Reviewer 2

The reviewer commented that it directly aligns with and supports all of VAN’s listed goals.

Reviewer 3

The reviewer commented that this research is highly relevant to VTO subprogram objectives, and that understanding the requirements to effectively deploy micromobility is a critical component of the overall transportation question.

Reviewer 4

The reviewer made no specific comments.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer mentioned that the resources are sufficient, and that the PI has met all of the milestones so far.

Reviewer 2

The reviewer noted that the resources are sufficient to complete the outlined scope of work for this project. The reviewer added that small project budgets make it difficult to bring in smaller organizations/additional partners as collaborators, potentially limiting the broader dissemination of results to interested stakeholders.

Reviewer 3

The reviewer stated that this project only has funding through U.S. government fiscal year 2022, but that it is scheduled to be complete in December 2022. This appears to the reviewer to be 2 months late, and the reviewer asked if an extension has been granted.

Reviewer 4

The reviewer made no specific comments.

Presentation Number: van045
Presentation Title: Analysis of Electric Heavy-Duty Driving and Infrastructure Requirements Within A Regional Area
Principal Investigator: Marcus Alexander, EPRI

Presenter

Marcus Alexander, EPRI

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

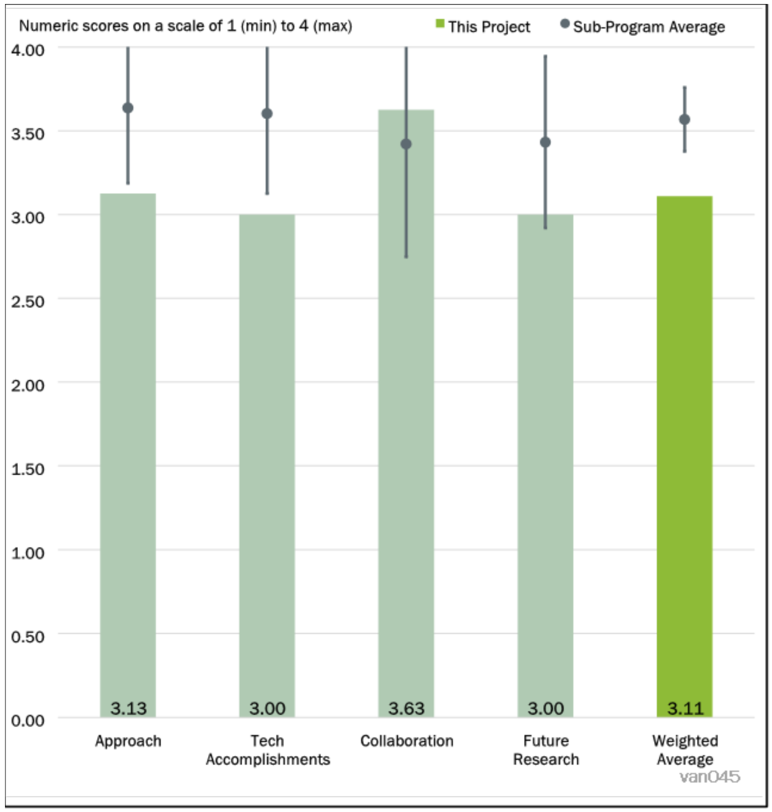

Figure 7-8 - Presentation Number: van045 Presentation Title: Analysis of Electric Heavy-Duty Driving and Infrastructure Requirements Within A Regional Area Principal Investigator: Marcus Alexander, EPRI

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer mentioned that the project combines NREL models of freight demand with real utility data on distribution infrastructure for urban and highway truck stop charging. The reviewer added that the NREL models make use of existing, open models, and that it's difficult to assess the quality of the analysis for the other project partners. The reviewer noted that even if specific model information/data cannot be provided, broad strokes about assumptions or general data sources, if they're publicly available, and model methodology would be helpful.

Reviewer 2

The reviewer mentioned that if successful, this project will directly address the listed barriers, specifically understanding how much it will cost to build out infrastructure for MD/HD electric vehicles. The reviewer commented that the approach is well designed and that it estimates where electricity will be needed (mission profile/load shape), how much it costs to get electricity to that location, and how much it costs to get the electricity into the truck at that location. The reviewer noted that one potential weak point is the voluntary participation of the grid/utility folks, although they might be sufficiently interested in and concerned about the impact of adding powerful EV chargers to their systems. The reviewer added that it is difficult to know how generalizable these results will be and is hopeful that the team will be able to shed some light on that in the final report/presentation.

Reviewer 3

The reviewer stated that the premise and purpose of this work is clear, but that the specific approach to be taken modeling the required charging infrastructure is lacking in details. The reviewer said that it is not fully clear what incremental work was done by NREL to their Fleet DNA tool, which has existed for some time, with respect to this activity, and why that work took a full year. It is also not clear to the reviewer what approach EPRI and Tri-State plan to take to their components of this project.

Reviewer 4

The reviewer made no specific comments.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

It appears to the reviewer that the team completed everything they expected to during the first year of the project, including derivation of truck load shapes, gathering/processing of utility data, and some of the modeling. The reviewer stated that as they stand, this sets a good foundation on which to complete full modeling in the second year.

Reviewer 2

The reviewer made no specific comments.

Reviewer 3

The reviewer noted that the freight data has been collected, and preliminary models of the urban depot distribution system modeling is reportedly completed. The reviewer said that the progress on the highway/truck stop modeling is less certain and was not detailed in this presentation. It was unclear to the reviewer what NREL's role in communicating with the unfunded/voluntary partner is and whether additional coordination was/will be necessary for this portion of the work.

Reviewer 4

The reviewer mentioned that the budget indicates funding in fiscal year 2021 and 2022, and that the project completion date is listed as March 2024. It is not clear to the reviewer how the project will be completed. The reviewer commented that based on the budget breakdown, it would be expected that the project be 50-60% complete at this point, but completion is shown only at the 30% level. The reviewer added that this gap is not addressed in the presentation, nor in the initial proposed project plan.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer stated that the project team appropriately distributes the technical work across experts in each space: NREL for transportation modeling, EPRI and Tri-State for grid modeling, and Salt River Project/Xcel Energy for site-specific information.

Reviewer 2

The reviewer noted that the coordination between EPRI, relevant utilities, and the NREL team modeling the freight demand seems to be making appropriate progress and is generally on track given the project timeline. The reviewer added that coordination with other partners seems to be a bit less clear, especially if they are to be included in the workshop or other public outputs from this work. The reviewer commented that additional details about the stakeholders that will be invited to the workshop would also be helpful. The reviewer asked if the workshop is just targeting the utilities that participated, other similar entities, or other DOE/lab organizations.

Reviewer 3

The reviewer noted that this project appears to have a strong cross functional team, but that further detail on the approach of each party would be appreciated.

Reviewer 4

The reviewer made no specific comments.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer noted that proposed future research appears to primarily fall within the initial scope as described.

Reviewer 2

The reviewer said that the team didn't propose any future work beyond completing this project. If successful, the reviewer hoped that the team will be able to expand to do similar analyses for other charging installations.

Reviewer 3

The reviewer made no specific comments.

Reviewer 4

The reviewer stated that the next phase of research involves completing the modeling of distribution systems to support freight charging infrastructure and beginning to investigate alternative technical solutions to reduce the cost of supporting this infrastructure. The reviewer added that the details about what technical alternatives (energy storage, distributed generation) will be included are a bit vague, and that it was unclear if the models exist to handle many possible technical scenarios easily or if it would be more helpful to select a few case studies or technologies to explore the existing design space of technical solutions.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer noted that the project has access to real-world transmission/distribution data, which is helpful for estimating the actual cost of urban and highway freight charging infrastructure, which is important for creating a pathway for electrified freight.

Reviewer 2

The reviewer stated that this is specifically relevant to the following VAN goal: Provide insight into transportation and energy use problems for a broad range of internal and external stakeholders. The reviewer mentioned that it will also help to create a solid foundation of data for VAN models that need MD/HD EV infrastructure costs and perhaps identify some key barriers that other pieces of the VTO portfolio should address.

Reviewer 3

The reviewer declared that the topic is relevant.

Reviewer 4

The reviewer said that the project addresses a major problem and presents a good opportunity to release information to agencies and the public.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer commented that the resources for this project appear to be sufficient.

Reviewer 2

The reviewer noted that much of the NREL portion of the scope of work seems to have been completed. The reviewer added that the EPRI preliminary results have been analyzed, although there may be difficulty allocating sufficient resources with the project budget to scope out different cost mitigation strategies mentioned in the "future work" portion of the presentation unless private funds are also available to supplement that work.

Reviewer 3

The reviewer declared that this project is at 30% completion and had used up about 55% of budget, assuming all fiscal year 2021 funds were spent. The reviewer noted that the project is scheduled to continue into March 2024, but that it has no fiscal year 2023 funding shown.

Reviewer 4

The reviewer made no specific comments.

Presentation Number: van046
Presentation Title: EVI-Equity
Principal Investigator: D-Y Lee, National Renewable Energy Laboratory

Presenter

D-Y Lee, NREL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

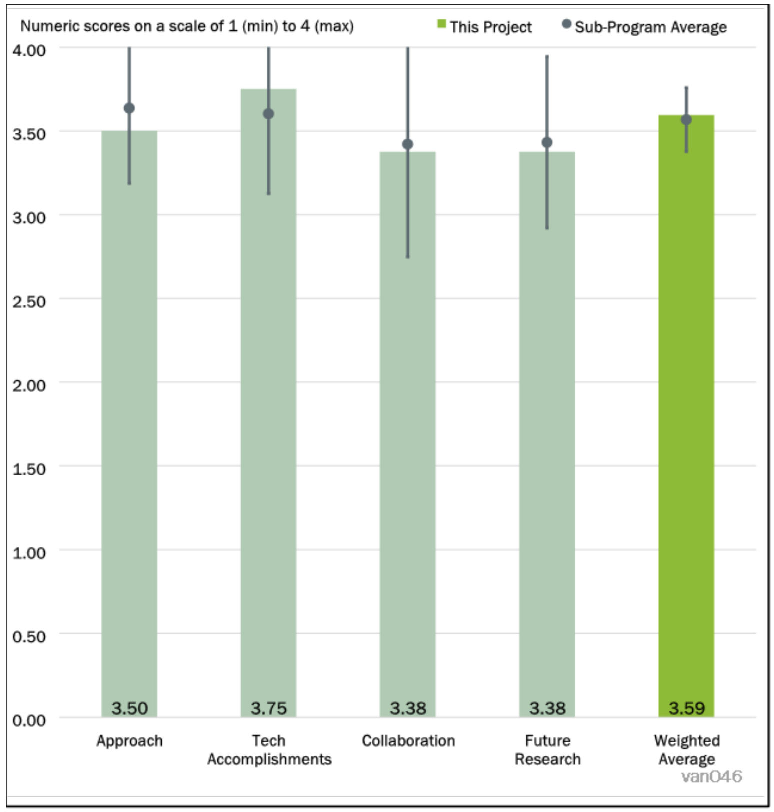

Figure 7-9 - Presentation Number: van046 Presentation Title: EVI-Equity Principal Investigator: D-Y Lee, National Renewable Energy Laboratory

Question 1: Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?

Reviewer 1

The reviewer noted that the project consisted of a survey about EV attitudes and preferences, which was used to determine the air quality that most EV owners are exposed to, relative to the general population. The reviewer added that similar geospatial estimates of the cost and energy burden associated with using public over private/home chargers was conducted. The reviewer stated that finally, some of the survey results were used to generate network scenarios that varied across one dimension (e.g., increasing access in low-income areas, or areas with more people of color) and showed the overall impact to the community in terms of EV access to charging and vehicles. The reviewer concluded that overall, the model is fairly simple in how it determines who is served by the new EV charger access; it does not currently account for trip distances or travel patterns, but is a first step.

Reviewer 2

The reviewer noted that a key barrier is the lack of a comprehensive, yet detailed, model/tool to evaluate equity of EV adoption and corresponding electric vehicle supply equipment (EVSE) infrastructure. The reviewer added that the project approach—creating a new EVI-Equity tool to juxtapose demographic variables, EVSE installations, and EV adoption—is a great step toward understanding the equity component of the EV rollout.

Reviewer 3

The reviewer mentioned that the team is clearly focused on understanding and quantifying specific barriers. The reviewer noted that it would have been interesting to see a bit more evaluation of the secondary market for electric vehicles and the cost and access to repair and for parts for second and third owners, but acknowledged that this market is nascent and that there may not be sufficient data to truly incorporate and generate effective conclusions.

Reviewer 4

The reviewer suggested that this project could use a discussion on stated vs. revealed preference.

Question 2: Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.

Reviewer 1

The reviewer noted that the majority of goals have been accomplished.

Reviewer 2

The reviewer noted that this was a single-year project, although the initial scope of work is somewhat unclear to assess whether the goals for this year have been met. The reviewer mentioned that the project team was able to field a survey to gather information on EV preferences and to construct a tool that generates two alternative scenarios of EV charging networks to improve equity along racial and economic dimensions.

Reviewer 3

The reviewer stated that the team has done a great job completing several specific analyses using the tool (case studies) and supporting the tool (surveys). The reviewer added that the team has successfully demonstrated how the tool can be used to estimate the equity impacts of EV charging siting and installation on EV adoption and on cost-to-charge for different demographics. The reviewer declared that the team analyzed how EVs impact equity through variation in price-to-charge ($/kWh), i.e., EV charging as “regressive”, or, the lower your income, the more you pay to drive. The reviewer emphasized that this piece is much more important and needs to be fleshed out more, perhaps in future work. The reviewer added that not only is EV cost-to-drive likely to be negatively correlated with income due to charging location type (residential versus public/multi-unit dwelling (MUD), but EV capital cost limitations will also likely constrain the business case for EVSE providers to install and operate EVSE in low-income communities in the first place; hence why they are installed between and around low-income communities rather than in and through them. The reviewer noted that it currently seems less like disadvantaging a community by intentionally skipping placement of a metro rail stop and more like a country club chain skipping over what is likely to be a failed location.

Reviewer 4

The reviewer made no specific comments.

Question 3: Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1

The reviewer commented that the project has several outside collaborators that have helped to provide input on the structure of distributional and geospatial models. The reviewer noted that future work is focused on incorporating many of the existing EVI tools, which seems to have overlap with the project team. The reviewer stated that more specific information about the collaborations with other DOE Office of Energy Efficiency and

Renewable Energy (EERE) offices beyond VTO would be helpful as these parallel projects work to address energy equity.

Reviewer 2

The reviewer noted an excellent team of collaborators to assist with collecting the data and providing feedback on concepts and methods for the tool. The reviewer added that the team also coordinated with NREL and led sessions with other agencies/organizations in order to solicit feedback.

Reviewer 3

The reviewer declared that there is a high level of collaboration across organizations. The reviewer said it would be interesting to see increased collaboration, or the mention of collaboration with underserved communities, tribes, and groups and their own representative organizations.

Reviewer 4

The reviewer suggested that more discussion here would be useful.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer noted that there were several targeted areas for proposed future work. The reviewer added that one area of focus was to include EVI tools to better predict demand for charging for personal vehicles and ridesharing. The reviewer suggested that additional information would be helpful in determining both the amount of travel demand that could be served if access to charging infrastructure was expanded, and if travel demand were itself more equitable than the current system. The reviewer mentioned that proposed future work about incorporating other vehicles is less clear. The reviewer stated that many heavy-duty vehicles within communities operate with centralized depots, so it is less clear that these vehicles would be as reliant on public EV chargers. The reviewer recommended that further differentiation between the vehicle uses (e.g., buses and paratransit vs. shipping) would likely be necessary to scope out this type of analysis.

Reviewer 2

The reviewer commented that proposed future work is all interesting and added that it feels a little early to be pushing distributional equity (if distributional equity is an end goal). The reviewer stated that this is not a mass-market technology as EVs are still 50% more expensive than the average LDV, and that the latter is already too expensive for low-income communities, and that therefore the business case for both chargers and vehicles would have to be sacrificed to make EVs accessible to all. The reviewer also suggested that exploring how far down market EVs would have to drop, and how much money EVSE providers would have to lose, for each kWh, to make EVs accessible to all, would be a helpful analysis to include alongside the demographic "state of play" assessment.

Reviewer 3

The reviewer was interested to see some non-academic outreach.

Reviewer 4

The reviewer made no specific comments.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer noted that the project provides useful information regarding distributional equity of EV resources (both personal vehicles and charging stations).

Reviewer 2

The reviewer stated that equity aligns with broader DOE Justice40 goals.

Reviewer 3

The reviewer declared that it is highly relevant and important work.

Reviewer 4

It was not clear to the reviewer if the final product is the results of the model or a model that individuals can run. The reviewer said that it is relevant in either case, but the use case is different.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated that the project resources are sufficient for completing the survey and the initial analysis included in the first year's scope of work.

Reviewer 2

The reviewer noted that the team has successfully reached its milestones so far and appears able to finish the remainder in time for the project end date.

Reviewer 3

The reviewer mentioned that it is on time, and on budget.

Reviewer 4

The reviewer made no specific comments.

Presentation Number: van047
Presentation Title: Integrated Modeling and Technoeconomic Assessment of Electric Vehicle Community Charging Hubs
Principal Investigator: Eleftheria Kontou, University of Illinois

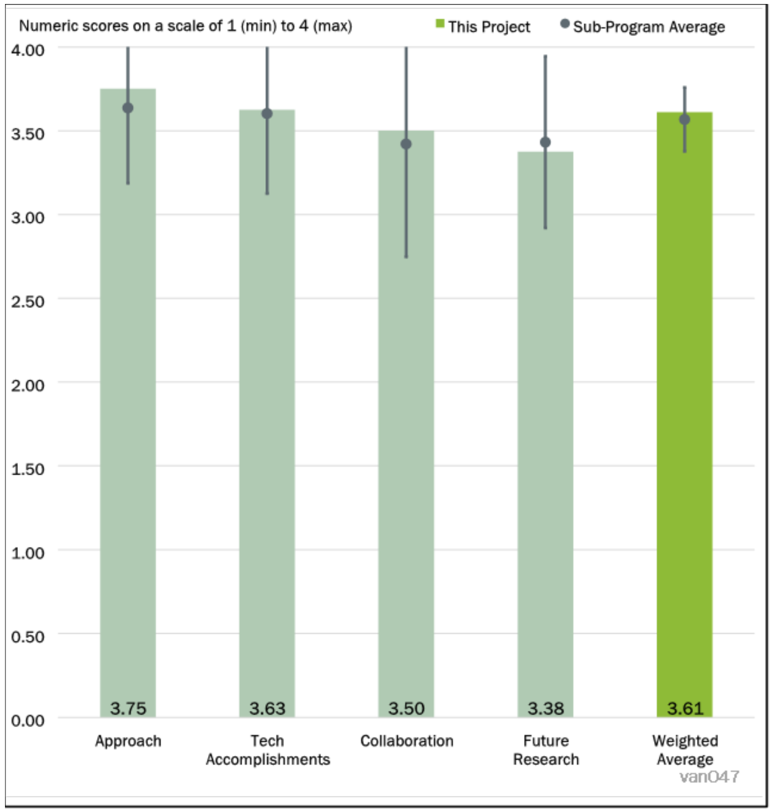

Figure 7-10 - Presentation Number: van047 Presentation Title: Integrated Modeling and Technoeconomic Assessment of Electric Vehicle Community Charging Hubs Principal Investigator: Eleftheria Kontou, University of Illinois

Presenter

Eleftheria Kontou, University of Illinois

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer stated that the project uses multiple combinations of charging technologies and business models to show the costs of systems with comparable performance in terms of wait time and cost, which is helpful for informing different infrastructure decisions. The reviewer added that the focus on multi-unit dwellings is important for expanding EV access.

Reviewer 2

The reviewer noted that the project is well-designed and proposes to address the key barrier (gaps in modeling/assessment of MUD EV charging hubs) through the development and application of an EV charge scheduling optimization tool. The reviewer added that the problem of EVSE management and optimization has been explored by a number of other publications, but that this project uniquely includes cost/kWh optimization for three different business models as well.

Reviewer 3

The reviewer would like to see a little more about how all the externalities of MUD parking situations are addressed in this study, such as visitor parking, requirements that vehicles be moved, but they are not, etc.

Reviewer 4

The reviewer made no specific comments.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer declared that the team completed analysis of three different metropolitan areas—Chicago, Los Angeles, and New York City—and is on track to complete the project on time. The reviewer commented that the team estimated the distribution of battery pack sizes for each, and then optimized charging infrastructure buildout and $/kWh pricing for a fleet of MUD vehicles in each. The reviewer said that this is a great step toward understanding how much it will actually cost to drive EVs for folks who don't have a private driveway/garage, and the reviewer is very interested in reading the paper when it is out.

Reviewer 2

The reviewer noted that the model has established three different test case cities, estimated the number of residents in the average multi-unit dwelling, determined typical travel patterns for those residents, and constructed charging infrastructure scenarios and business models to meet that projected demand.

Reviewer 3

The reviewer mentioned that the project has accomplished its stated goals.

Reviewer 4

The reviewer made no specific comments.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer noted that the project includes partners at ANL and collaborates with the Chicago Clean Cities Coalition, and that there are plans for open-source access to the model and publications/summaries for a more general non-academic audience.

Reviewer 2

The reviewer said that the team has specific contributions from ANL and is collaborating with appropriate government entities like Clean Cities and Illinois Department of Transportation.

Reviewer 3

The reviewer mentioned a multi-partner collaboration, but that it would have been nice to see some collaboration with commercial charging providers.

Reviewer 4

The reviewer commented that more discussion on collaboration would be useful here.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer noted that future work includes providing open access to the model, incorporating charging in mixed use developments, and addressing techno-economic uncertainty. The reviewer suggested potentially exploring the variability of the power supplied for fast charging as each EV has its own "signature" charge profile. The reviewer added that this variability may also have behavioral implications: fast charging usually only works until the batteries reach some threshold state of charge (usually 80%-90% state of charge), and then charge at a "normal" rate. The reviewer mentioned that it may be helpful to consider that residents or customers charging during the day may value the fast and slow charge differently.

Reviewer 2

The reviewer stated that proposed future research goals are justified and would further expand the explanatory power of this analysis framework. The reviewer added that understanding the variety of charging behaviors will widen the resulting costs and waiting times, but it would be a valuable exercise for many stakeholders.

Reviewer 3

The reviewer expressed interest in seeing more on the configuration of MUDs and the behavioral impacts of charging location and requirements.

Reviewer 4

The reviewer made no specific comments.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer mentioned that the project provides information regarding the cost and performance in terms of wait times of multi-unit vehicle charging, a key component to further increasing EV adoption in a more economically-diverse cross section of communities. The reviewer added that the project also provides information on how business models and different technology combinations can provide similar levels of service.

Reviewer 2

The reviewer said that the research is aligned with the VTO mission of accelerating the development and widespread use of innovative transportation technologies and enabling equitable access to electric vehicle charging.

Reviewer 3

The reviewer stated that the research is relevant to the subprogram objectives.

Reviewer 4

The reviewer made no specific comments.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer said that the project resources are sufficient for completing publication of previous results and for completing the scoped future work.

Reviewer 2

The reviewer noted that the resources appear to be sufficient.

Reviewer 3

The reviewer commented that the project appears to be on time and on budget.

Reviewer 4

The reviewer made no specific comments.

Presentation Number: van048
Presentation Title: Heavy-Duty Electric Vehicle Integration and Implementation (HEVII) Tool
Principal Investigator: William Northrop, University of Minnesota

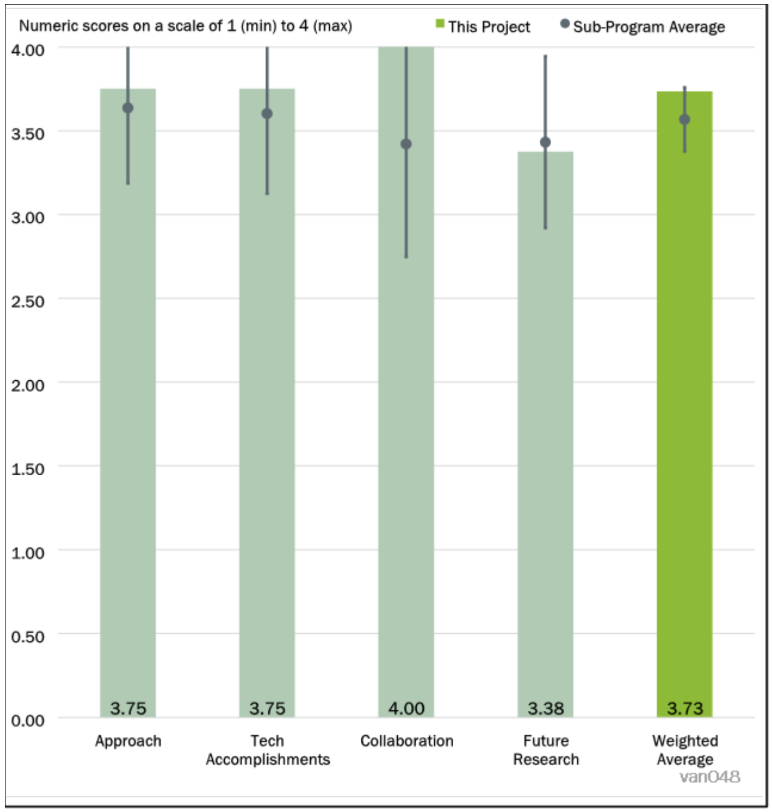

Figure 7-11 - Presentation Number: van048 Presentation Title: Heavy-Duty Electric Vehicle Integration and Implementation (HEVII) Tool Principal Investigator: William Northrop, University of Minnesota

Presenter

William Northrop, University of Minnesota

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: *Approach to Performing the Work: Is the project well designed, and is the timeline reasonably planned?*

Reviewer 1

The reviewer said that this project addresses a major barrier to understanding the electrification potential of commercial fleets, which is payload weight across a full vehicle mission or trip. The reviewer added that the team's approach is to use data from on-board loggers, and Fast-Sim, to estimate vehicle weight and the corresponding battery size, charge rate, and infrastructure location requirements. The reviewer agreed that this is a good approach and should produce some novel data that will be highly valuable for a number of VTO and other stakeholders.

Reviewer 2

The reviewer noted the solid premise to model electrification requirements for fleets.

Reviewer 3

The reviewer stated that the project combined real fleet data from fleet operators and the producers of commercial fleet data loggers to gather data about the trips made by fleet vehicles. The reviewer added that the data was then used to estimate vehicle mass as fuel is consumed in ICE vehicles and deliveries are made. The reviewer noted that this model outperformed physics-based models using a constant vehicle mass, and that it used the information about fleet travel patterns to identify areas, in the form of hexagonal cells, where there is significant driver activity. The reviewer added that, while this is helpful to have, it is less clear whether a) there is a coincidence of busy traffic areas, b) if the driver activity in an area is already driven by refueling considerations, or c) if those high traffic areas are well-aligned with EV charging demands.

Reviewer 4

The reviewer made no specific comments.

Question 2: *Technical Accomplishments and Progress: Comments on the technical progress that has been made compared to project plan.*

Reviewer 1

The reviewer stated that the project has conducted significant portions of the analysis with additional iterations using more consistent data and for different vehicle fleets.

Reviewer 2

The reviewer noted that the team completed several key tasks, including collecting data from 24 diesel Class 6-8 vehicles, validating the mass prediction model, and determining baseline fleet charger locations. The reviewer added that this lays the groundwork for the EV analysis component of the project.

Reviewer 3

The reviewer said that the milestone numbers appear to be confounded between Slides 3 and 6-8. The reviewer mentioned that the progress appears to match the target, but that it is a little unclear in the presentation materials without a speaker.

Reviewer 4

The reviewer made no specific comments.

Question 3: *Collaboration and Coordination Across Project Team: Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?*

Reviewer 1

The reviewer noted that the close partnership between the collaborators was critical in getting access to fleet vehicle travel patterns and improving the collection of data at a consistent frequency.

Reviewer 2

The reviewer said that the University of Minnesota is collaborating with the right folks for this work: NREL, which has experience with FleetDNA data and is also the home of FastSim; PepsiCo, which is a test fleet; and Geotab, which has a long history of analysis on data logger data.

Reviewer 3

The reviewer noted excellent cross-functional collaboration with parties from multiple sectors working together.

Reviewer 4

The reviewer commented that this is one of the better showcases of both academia and multiple industry players providing their expertise to solve a problem. The reviewer added that it is refreshing to see industry change their product to make data collection for research easier.

Question 4: *Proposed Future Research: Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?*

Reviewer 1

The reviewer mentioned that the remaining work focuses on further refinement of an existing model, using additional fleet travel patterns as a test case, and publishing the code to a repository.

Reviewer 2

The reviewer said that proposed future work, including expanding the tool to other vehicle data sets and creating a GUI, would be valuable. The reviewer expressed uncertainty about such a small sample (24 trucks, single fleet) and whether it would be generalizable. The reviewer suggested that the future work should focus on the former (more data) rather than the latter (public-facing tool).

Reviewer 3

It is a little unclear to the reviewer what the difference between the proposed tool and the future proposed tool with a simpler user interface will be.

Reviewer 4

The reviewer would like to see validation for other users. The reviewer added that there needs to be safeguards to ensure that the solution is not inadvertently tuned to the development scenario (i.e., a single industrial customer) and that it is transferable.

Question 5: *Relevance: Does the project support the overall VTO subprogram objectives?*

Reviewer 1

The reviewer commented that understanding how fuel consumption varies over the course of medium- and heavy-duty drive cycles is important in correctly estimating the demand for EV charging that would need to be met, either with privately-operated mini depots or public chargers.

Reviewer 2

The reviewer mentioned that this work is relevant to VAN's goal of providing insight into transportation and energy use problems for a broad range of internal and external stakeholders, as well as all three of the broader objectives in support of VAN goals.

Reviewer 3

The reviewer said that the project is relevant to subprogram objectives.

Reviewer 4

The reviewer made no specific comments.

Question 6: *Resources: Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?*

Reviewer 1

The reviewer stated that the resources are sufficient to complete the outlined scope of work for this project.

Reviewer 2

The reviewer said that the team and resources seem sufficient for the planned work.

Reviewer 3

The reviewer noted that, as reported, this is a little confusing. The reviewer clarified that the project is reported as 75% complete, with a final completion date of 12/31/2022, but based on the numbers reported, it appears that only about 51% of the project funding has been used. It is not clear to the reviewer if it is planned to have increased funding requirements later in the project cycle, or why this mismatch is occurring.

Reviewer 4

The reviewer made no specific comments.

Acronyms and Abbreviations

ADAS	Advanced driver-assistance system
ADOPT	Automotive Deployment Options Projection Tool
AEO	Annual Energy Outlook
ANL	Argonne National Laboratory
API	Application programming interface
BatPac	Battery Performance and Cost
CAFE	Corporate average fuel economy
DEIA	Diversity, Equity, Inclusion and Accessibility
DOE	U.S. Department of Energy
EIA	Energy Information Administration
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
EV	Electric vehicle
FOTW	Fact of the Week
GHG	Greenhouse gas
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Transportation model
HDV	Heavy-duty vehicle
HPC	High performance computing
ICE	Internal combustion engine
LCA	Life-cycle analysis
LDV	Light-duty vehicle
MD	Medium-duty
MUD	Multi-unit dwelling
NREL	National Renewable Energy Laboratory
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PI	Principal Investigator
TCO	Total cost of ownership
TEDB	Transportation Energy Data Book
VAN	Vehicle Analysis Program
VIUS	Vehicle Inventory and Use Survey

VTO	Vehicle Technologies Office
kWh	Kilowatt hour

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8. Acronyms and Abbreviations

°C	Degrees Celsius
21CTP	21st Century Truck Partnership
3-D	Three-dimensional
ACC	Adaptive cruise control
ACE	Advanced Combustion Engines
ACEEE	America Council for an Energy-Efficient Economy
ACI	Advanced compression ignition
ACM	American Center for Mobility
ADAS	Advanced driver-assistance system
ADOPT	Automotive Deployment Options Projection Tool
AEO	Annual Energy Outlook
AFDC	Alternative Fuels Data Center
AFV	Alternative fuel vehicle
Ah	Ampere hour
AI	Artificial intelligence
Al	Aluminum
AM	Additive manufacturing
AMR	Annual Merit Review
ANL	Argonne National Laboratory
API	Application programming interface
APS	Advanced Photon Source
ARL	U.S. Army Research Laboratory
ARPA-E	U.S. Department of Energy Advanced Research Projects Agency-Energy
ASTM	American Society for Testing and Materials
BatPac	Battery Performance and Cost
BEAM	Behavior, Energy, Autonomy, and Mobility
BEAM CORE	Behavior, Energy, Autonomy, and Mobility Comprehensive Regional Evaluator
BEV	Battery-electric vehicle
BG&E	Baltimore Gas & Electric
BNL	Brookhaven National Laboratory

BOB	Blendstocks for oxygenate blending
BP	Budget Period
BSFC	Brake specific fuel consumption
BTE	Brake thermal efficiency
BTFE	bis(2,2,2-trifluoroethyl) ether
BWI	Baltimore/Washington International Airport
C	Charge rate
CAFE	Corporate average fuel economy
CAM	Cathode active material
CAMP	Cell Analysis, Modeling, and Prototyping Facility
CAN	Controlled area network
CARB	California Air Resources Board
CARMA	Cooperative automation research mobility applications
CAV	Connected and automated vehicle
CAVE	Connected and Automated Vehicle Environment
CBO	community-based organizations
CCF	Carbon-carbon fiber
CDA	Cylinder deactivation
CDA	Cooperative driving automation
Ce	Cerium
CE	Coulombic efficiency
CEI	Cathode-electrolyte interface
CeO_2	Ceria
CF	Carbon fiber
C-F	Carbon-fluorine
CFD	Computational fluid dynamics
CFM	Complex framework materials
CFO	Clean Fuels Ohio
CFR	Cooperative Fuel Research
CFRC	Carbon fiber reinforced composite
CFRP	Carbon fiber reinforced polymer
CFTF	Carbon Fiber Technology Facility

CI	Carbon intensity
CI	Compression-ignition
CIP	Contact ion pairs
cm	Centimeter
CMU	Carnegie Mellon University
CNG	Compressed natural gas
CNT	Carbon nanontube
CO	Carbon monoxide
Co	Cobalt
CO_2	Carbon dioxide
COVID-19	Coronavirus disease 2019
Cr	Chromium
CRADA	Cooperative research and development agreement
CRT	Continuously regenerating trap
CS	Cooled spray
CT	Computerized tomography
CTE	Coefficient of thermal expansion
Cu	Copper
CV2X	Cellular vehicle-to-everything
CVD	chemical vapor deposition
DC	Direct current
DC/DC	Direct current/direct current
DEIA	Diversity, Equity, Inclusion and Accessibility
DEMS	Differential Electrochemical mass spectroscopy
DFI	Ducted fuel injection
DFT	Density function theory
DFT	Discrete Fourier transform
DI	Direct injection
DIC	Digital image correlation
DMC	Dimethyl carbonate
DME	Dimethyl ether
DNS	Direct numerical simulation

DOC	Diesel oxidation catalyst
DOC-F	Combined diesel oxidation catalyst and diesel particulate filter
DOE	U.S. Department of Energy
DOT	[state or city] Department of Transportation
DOT	U.S. Department of Transportation
DOTs	Departments of Transportation
DPF	Diesel particulate filter
DRIFTS	Diffuse reflectance infrared Fourier transform microscopy
DSF	Dynamic skip-fire
DSRC	Dedicated short-range communication
DWPT	Dynamic wireless power transfer
E10	10% ethanol, 90% gasoline fuel blend
E100	100% ethanol, 0% gasoline fuel blend
E85	85% ethanol, 15% gasoline fuel blend
EC	Ethylene Carbonate
Eco ATCS	Ecological Adaptive Traffic Control System
EDAX	Energy dispersive X-Ray analysis
EDT	Electric Drive Technology(ies)
EDU	Electric drive unit
EEJ	Energy and Environmental Justice
EEMS	Energy Efficient Mobility Systems program
EERE	Office of Energy Efficiency and Renewable Energy
EGR	Exhaust gas recirculation
EIA	Energy Information Administration
EIS	Electrochemical impedance spectroscopy
EJ	Environmental Justice
ELT	Electrification program
EM	Electromagnetic
EMA	Engine Manufacturers Association
EMC	Electromagnetic compatibility
EMI	Electromagnetic interference
EPA	U.S. Environmental Protection Agency

EPD	Electrophoretic deposition
EPR	Electron paramagnetic resonance spectroscopy
EPRI	Electric Power Research Institute
EV	Electric vehicle
EVI	Electric vehicle infrastructure
EVs@Scale	Electric Vehicles at Scale Consortium
EVSE	Electric vehicle supply equipment
EVSP	Electric vehicle service provider
EZMT	Energy Zones Mapping Tool
Fe	Iron
FEA	Finite element analysis
FEC	Fluoroethylene carbonate
FEC	Functional electrocatalysts
FEMC	Methyl 2,2,2-Trifluoroethyl Carbonate
FHWA	Federal Highway Administration
FLHCE	Fluorinated localized high-concentration electrolyte
FM/LM	First mile/last mile
FOA	Funding opportunity announcement
FOTW	Fact of the Week
FRESCO	Fast, Robust Engine Simulation Code
FSLW	Friction-stir linear welding
FSP	Friction-stir processing
F-SPR	Friction self-piercing rivet
FSW	Friction-stir weld(ing)
FTE	Freight-ton efficiency
FTE	Full-time equivalent
FTIR	Fourier-transform infrared spectroscopy
FTP	Federal Test Procedure
FUSE	Flexible charging to Unify the grid and transportation Sectors for EVs at scale
FY	Fiscal Year
FY	Fiscal Year
g	gram

g/hp-hr	Gram per horsepower-hour
GaN	Gallium nitride
GBA	γ-butyrolactone
GCB	Graphene-enriched carbon black
GHG	Greenhouse gas
GHG	Greenhouse gas
GM	General Motors
GPa	Gigapascal
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Transportation model
GSU	Georgia Southern University
GT-Power	Gamma Technologies - Power
H_2	Hydrogen
HBCU	Historically Black Colleges and Universities
HC	Hydrocarbon
HD	Heavy-duty
HDOT	Hawaii Department of Transportation
HDPE	High-density polyethylene
HDV	Heavy-duty vehicle
HELICS	Hierarchical Engine for Large-scale Infrastructure Co-Simulation
HEV	Hybrid electric vehicle
HFR	High-rate friction rivet
HIL	Hardware-in-the-loop
HMI	Human-machine interface
HPC	High-performance computing
HPC	High-power charging
HPC	High-performance computing
HPDC	High-pressure die casting
HRE	Heavy rare earth
HRTEM	High-resolution transmission electron microscopy
HTC	High temperature carbonization
HVAC	Heating, ventilation, and air conditioning
HVO	Hydrotreated vegetable oil

HVR	High-velocity rivet
HyFi	Hybrid nanocomposite fibers
IACMI	Institute for Advanced Composites Manufacturing Innovation
IARIA	International Academy, Research and Industry Association
ICE	Internal combustion engine
ICME	Integrated computational materials engineering
IIC	Indiana Integrated Circuits
IIT	Illinois Institute of Technology
IMEP	Indicated mean effective pressure
IMSwTPG	Insulated metal substrate with thermally annealed pyrolytic graphite
IMU	Inertial measurement unit
INEXUS	Individual Experienced Utility-based Synthesis
INL	Idaho National Laboratory
IP	Intellectual property
IPM	Interior permanent magnets
ISO	International Organization for Standardization
ITE	Indicated thermal efficiency
ITS	Intelligent Transportation Systems
JBS	Junction barrier Schottky
JPO	Joint Programs Office
kg	Kilogram
ksi	Thousand pounds per square inch
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt hour
L	Liter
lb	Pound
LBNL	Lawrence Berkeley National Laboratory
LCA	Life-cycle analysis
LD	Light-duty
LDV	Light-duty vehicle
LES	Large eddy simulation

LFP	Lithium iron phosphate
LHCE	Localized high-concentration electrolyte
Li	Lithium
LiDAR	Laser imaging, detection, and ranging
LiF	Lithium fluoride
LiFSI	Lithium bis(fluorosulfonyl)imide
LightMAT	Lightweight Materials Consortium
Li-ion	Lithium-ion
$LiPF_6$	Lithium hexafluorophosphate
Li-S	Lithium-sulfur
Li-TFSI	Lithium bis(trifluoromethanesulfonyl)imide
LLCF	Low life-cycle carbon fuels
LLNL	Lawrence Livermore National Laboratory
LLZO	Lithium lanthanum zirconium oxide
LMCP	Light Metals Core Program
LO	Light-off
LPG	Liquified petroleum gas (propane)
LSE	Localized saturated electrolyte
LT	Low-temperature
LTHR	Low temperature heat release
LTP	Low-temperature plasma
MA	Methyl acetate
mAh	Milliamp-hour
MAS	Micro-alloyed steel
MAT	Materials Technology Program
MD	Medium-duty
MEP	Mobility Energy Productivity
Mg	Magnesium
ML	Machine learning
mm	Millimeter
MMC	Metal matrix composite
Mn	Manganese

MOC	Mesoporous ordered ceramic
MOF	Metal organic framework
MON	Motor octane number
MOSFET	Metal-oxide semiconductor field-effect transistor
MOTION	MObility Technology Interstate Observation Network
MOVES	MOtor Vehicle Emission Simulator
MP	Methyl propionate
MPa	Megapascal
mph	Miles per hour
MPO	Metropolitan planning organization
MR	MOLECULAR REBAR®
MRL	Manufacturing Readiness Levels
msi	Million pounds per square inch
MSU	Mississippi State University
MTT	Materials Technical Team
MTU	Michigan Technological University
MUD	Multi-unit dwelling
MW	Megawatt
Mw	Molecular weight
MWBE's	Minority and women owned business enterprise
MWh	Megawatt hour
N/P	Negative electrode to positive electrode capacity ratio
N_2O	Nitrous oxide
NA	$LiNi_{0.95}Al_{0.05}O_2$
NAFA	National Association of Fleet Administrators
NASEO	National Association of State Energy Officials
NATM	Co- and Mn-Free $LiNi_{0.93}Al_{0.05}Ti_{0.01}Mg_{0.01}O_2$
Nb	Niobium
NBR	Nitrile rubber (nitrile-butadiene rubber)
NC	$LiNi_{0.94}Co_{0.06}O_2$
NCA	Nickel cobalt aluminum oxide
NECST	Nanomaterials for Energy Conversion Storage Technology

NEMA	National Electrical Manufacturers Association
NEVI	National Electric Vehicle Infrastructure
NH_3	Ammonia
NHTSA	National Highway Traffic Safety Administration
Ni	Nickel
nm	Nanometer
NM	$LiNi_{0.95}Mn_{0.05}O_2$
NMC	Nickel manganese cobalt oxide
NMR	nuclear magnetic resonance
NO	Nitric oxide (nitrogen monoxide)
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
NRC-Canada	National Research Council-Canada
NREL	National Renewable Energy Laboratory
NVH	Noise, vibration, and harshness
O	Atomic oxygen
OCPP	Open charge point protocol
ODBC	Organic direct-bond copper
ODD	Operational design domain
OEM	Original equipment manufacturer
OP2S	Opposed piston two-stroke
ORNL	Oak Ridge National Laboratory
OSU	Ohio State University
PAC	Project advisory committee
PAEK	polyaryletherketone
PAG	polyalkylene glycols
PAH	Polycyclic aromatic hydrocarbon
PAN	Polyacrylonitrile
PATH	Partners for Advanced Transportation Technology
PCB	Printed circuit board
Pd	Palladium
PDF	Pair-distribution function

PE	Polyethylene
PEAK	Polyaryletherketone
PEC	Pareto-efficient combustion
PECVD	Plasma-enhanced chemical vapor deposition
PEO	Polyethylene oxide
PERC	Propane Education and Research Council
PEV	Plug-in electric vehicle
PFPE	Perfluoropolyether
PFR	Plasma flow reactor
PGM	Platinum group metals
PHEV	Plug-in hybrid electric vehicle
PI	Principal investigator
PM	Particulate matter
PM	Permanent Magnet
PNNL	Pacific Northwest National Laboratory
POCs	Porous and mesoporous ordered ceramics
POFM	Porous organometallic framework materials
POLARIS	Planning and Operations Language for Agent-based Regional Integrated Simulation
PP	Polypropylene
PRF	Primary reference fuels
PSU	Pennsylvania State University
PTA	Polysulfide trapping additives
PU	Polyurethane
PUSP	Power ultrasonic surface processing
PVC	Polyvinyl chloride
PVDF	Polyvinylidene fluoride
PVP	Polyvinylpyrrolidone
Q&A	Question and answer
R&D	Research and development
RANS	Reynolds-averaged Navier-Stokes
RCM	Rapid compression machine
RDD&D	Research, development, deployment, and demonstration

RE	Rare earth
REV	Regional Electric Vehicle
Rh	Rhodium
RNG	Renewable natural gas
ROI	Return on investment
RON	Research octane number
rpm	Revolutions per minute
RWA	Real-world aging
S	Sulfur
SAC	Single-atom catalyst (catalysis)
SAE	Society of Automotive Engineers
SAE	Society of Automotive Engineers
SBIR	Small Business Innovation Research
SCAQMD	South Coast Air Quality Management District
SCE	Single-cylinder engine
SCI	Structural Composites, Inc.
SCM	Smart charge management
SCR	Selective catalytic reduction
SCRF	Selective catalytic reduction on filter
SEI	Solid-electrolyte interface
SEM	Scanning electron microscopy
SET	Supplemental Emissions Test
ShAPE™	Shear Assisted Processing and Extrusion
SI	Spark ignition
Si	Silicon
SiC	Silicon carbide
SIMS	Secondary Ion Mass Spectrometry
SLAC	Stanford Linear Accelerator Center
SMART	Systems and Modeling for Accelerated Research in Transportation
SNL	Sandia National Laboratories
SoC	State of charge
SO_x	Sulfur oxides

SPAN	Sulfurized polyacrylonitrile
SPH	Smoothed Particle Hydrodynamics
SPR	Self-piercing rivet
SRNL	Savannah River National Laboratory
SSAM	Surrogate Safety Assessment Model
SSCB	Solid state circuit breakers
SST	Solid-state transformer
STEM	Scanning transmission electron microscopy
SUMO	Simulation of Urban MObility
SURF	Scale-Up Research Facility
SVPWD	Space vector pulse width modulation
SVTRIP	Stochastic vehicle trip prediction
SwRI	Southwest Research Institute
TAT	Traffic Analysis Toolbox
TCO	Total cost of ownership
TEA	Techno-economic analysis
TEDB	Transportation Energy Data Book
TEM	Transmission electron microscopy
TFEPE	1,1,2,2-tetrafluoroethyl n-propyl ether
TFP	Tailored fiber placement
T_g	Glass transition temperature
TI	Technology Integration
Ti	Titanium
TiB_2	Titanium diboride
TMS	Thermal management system
TNC	Transportation network companies
ToF	Time-of-Flight
TOU	Time of use
TPM	Thermo-Pseudo Mechanical
TRL	Technology readiness level
TuFF	Tailorable universal feedstock for forming
TVA	Tennessee Valley Authority

TWC	Three-way catalyst
TXM	Transmission X-ray microscopy
U.S.	United States
U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability
UAM	Ultrasonic additive manufacturing
UAV	Unmanned aerial vehicle
UCC	Ultra-conducting copper
UCLA	University of California at Los Angeles
UCONN	University of Connecticut
UCSD	University of California-San Diego
UHMWPE	Ultra-high-molecular-weight polyethylene
UL	Underwriters' Laboratory
$ULNO_x$	Ultra-Low Nitrogen Oxides
UNM	University of New Mexico
UNT	University of North Texas
UPS	United Parcel Service
USABC	United States Advanced Battery Consortium
USAMP	U.S. Automotive Materials Partnership
USCAR	United States Council for Automotive Research
USPS	United States Postal Service
UT	University of Tennessee
UT	University of Texas
UV	Ultraviolet
UW	University of Wisconsin
V	Volt
V2G	Vehicle-to-grid
V2I	Vehicle-to-infrastructure
V2V	Vehicle-to-vehicle
V2X	Vehicle-to-anything
VAN	Vehicle Analysis Program
VARTM	Vacuum assisted resin transfer molding

VFAW	Variable frequency arc welding
Vhold	Voltage hold
VIL	Vehicle-in-the-loop
VIUS	Vehicle Inventory and Use Survey
VOICES	Virtual Open Innovation Collaborative Environment for Safety
VTO	Vehicle Technologies Office
VTOL	Vertical take-off and landing
WBG	Wide bandgap
Wh	Watt-hour
WHR	Waste heat recovery
WPT	Wireless power transfer
WSU	Washington State University
WVU	West Virginia University
XFC	eXtreme fast charging
XIL	Everything-in-the-loop
XRD	X-ray diffraction
ZEV	Zero-emission vehicle
Zn	Zinc
Zr	Zirconium
µm	Micrometer

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