2. Electrification

The Vehicle Technologies Office (VTO) supports research, development, demonstration, and deployment (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 innovations in connected infrastructure for significant systems-level energy efficiency improvement); innovative powertrains to reduce greenhouse gas (GHG) and criteria emissions from hard to decarbonize off-road, maritime, rail, and aviation sectors; and technology integration that helps demonstrate and deploy new technology at the community 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), VTO 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 Electrification 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 four distinct crosscuts including: Critical Materials, Grid Modernization, Advanced Manufacturing, and Energy Sector Cybersecurity.

The Electric Drive research and development (R&D) activity supports R&D for extreme high-power density electric drive systems that have the potential to enable radical new vehicle architectures by dramatic volume/space reductions and increased durability and reliability. The cost of electric traction drive systems, including power electronics and electric motors, will be reduced through high-density integration technologies, novel circuit topologies, new materials for high-density electric motors, and leveraging high performance computing for modeling and optimization. VTO will use electric traction drive system design, integration, and testing to verify performance and progress towards meeting R&D targets.

Electrification R&D: The Electrification R&D activity supports R&D to understand the potential impacts on, and benefits of, EV 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 plug-in electric vehicle (PEV) refueling through extreme fast charging. Core research focuses on developing EV charging, charge management, distributed energy resources (DER) integration, grid services, and cyber-physical security technologies for reliable and cost-effective charging of light-, medium-, and heavy-duty (HD) electric vehicles (EV). This includes technical support and research for technologies related to cybersecurity for 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 2-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaboration	Future Research	Weighted Average
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])	2-6	3.33	2.92	3.58	3.08	3.13
ELT179	Low Cost, High-Performance, Heavy Rare-Earth-Free 3-In-1 Electric Drive Unit	David Crecelius (American Axle & Manufacturing)	2-12	3.50	3.33	3.00	3.33	3.33
ELT197	High Power and Dynamic Wireless Charging of Electric Vehicles	Veda Galigekere (Oak Ridge National Laboratory)	2-15	3.60	3.60	3.40	3.30	3.54
ELT208	Highly Integrated Power Module	Lincoln Xue (Oak Ridge National Laboratory)	2-20	3.33	3.33	3.50	3.17	3.33
ELT209	High-Voltage, High-Power Density Traction-Drive Inverter	Gui-Jia Su (Oak Ridge National Laboratory)	2-23	3.25	3.63	3.13	3.38	3.44
ELT211	Power Electronics Thermal Management	Gilbert Moreno (National Renewable Energy Laboratory)	2-27	3.67	3.67	3.58	3.17	3.59
ELT215	Develop fine-grain RE permanent magnet with high coercivity at high temperature AND cost-effective manufacturing process for high performance soft magnetic materials in thin sheet form	Iver Anderson (Ames Laboratory)	2-32	3.00	3.10	2.80	3.00	3.03

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaboration	Future Research	Weighted Average
ELT216	Isotropic, Bottom-Up Soft Magnetic Composites for Rotating Machines	Todd Monson (Sandia National Laboratories)	2-36	3.30	3.30	3.40	3.30	3.31
ELT219	Power Electronics Materials and Bonded Interfaces-Reliability and Lifetime	Paul Paret (National Renewable Energy Laboratory)	2-40	3.42	3.42	3.17	3.42	3.39
ELT221	Integrated Electric Drive System	Shajjad Chowdhury (Oak Ridge National Laboratory)	2-44	3.00	3.25	3.13	3.13	3.16
ELT223	Component Testing, Co-Optimization, and Trade-Space Evaluation	Jason Neely (Sandia National Laboratories)	2-47	3.33	3.33	2.83	3.33	3.27
ELT236	Direct-Current Conversion Equipment Connected to the Medium-Voltage Grid for Extreme Fast Charging Utilizing Modular and Interoperable Architecture	Watson Collins (Electric Power Research Institute)	2-50	3.38	3.00	3.00	3.38	3.14
ELT238	Intelligent, Grid-Friendly, modular Extreme Fast Charging System with Solid-State Direct-Current Protection	Srdjan Lukic (North Carolina State University)	2-54	3.67	3.50	3.50	3.25	3.51
ELT239	High-Power Inductive Charging System Development and Integration for Mobility	Omer Onar (Oak Ridge National Laboratory)	2-58	3.50	3.50	3.38	3.50	3.48
ELT240	Wireless Extreme Fast Charging for Electric Trucks (WXFC-Trucks)	Ryan Calder (WAVE, Inc.)	2-62	2.83	3.00	2.83	3.00	2.94
ELT252	Wound-Field Synchronous Machine-System Integration toward Increased Power Density and Commercializatio n	Lakshmi Iyer (Magna Services of America Inc)	2-65	3.25	3.75	3.25	3.00	3.47

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaboration	Future Research	Weighted Average
ELT255	Cost-Effective, Rare-Earth-Free, Flux-Doubling, Torque-Doubling, Increased Power Density Traction Motor with Near-Zero Open-Circuit Back-Electromagnetic Field and No-Cogging Torque	Jim Gafford (University of North Carolina at Charlotte)	2-68	2.83	3.00	3.00	2.83	2.94
ELT260	Improving the Freight Productivity of a Heavy-Duty, Battery Electric Truck by Intelligent Energy Management	Teresa Taylor (Volvo)	2-70	2.75	2.75	2.83	2.50	2.73
ELT261	High-Efficiency Powertrain for Heavy-Duty Trucks using Silicon Carbide Inverter	Steve Peelman (Ricardo)	2-75	3.33	3.17	3.00	3.33	3.21
ELT262	Long-Range, Heavy-Duty Battery-Electric Vehicle with Megawatt Wireless Charging	Ryan Reed (Kenworth)	2-78	3.00	3.13	3.00	3.00	3.06
ELT264	Demonstration of Utility Managed Smart Charging For Multiple Benefit Streams	Stephanie Leach (Exelon/Pepco Holdings Inc.)	2-81	3.25	3.25	3.00	3.25	3.22
ELT265	A Secure and Resilient Interoperable SCM Control System Architecture for Electric Vehicle‘s-At-Scale	Duncan Woodbury (Dream Team LLC)	2-84	3.00	3.00	3.00	3.00	3.00
ELT274	eMosaic, Electrification Mosaic Platform for Grid-Informed Smart Charging Management	Alex Brissette (ABB)	2-87	3.33	3.17	3.17	2.67	3.15
ELT278	EVs@Scale Lab Consortium	Andrew Meintz (National Renewable Energy Laboratory)	2-90	3.00	2.83	2.50	3.00	2.85

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaboration	Future Research	Weighted Average
ELT282	Technology & Design Innovations to Maximize the Reduction Effect on DCFC Unit Cost Economics (Max-REDUCE)	Robert Keefover (Borg Warner)	2-94	3.50	3.25	3.25	2.25	3.19
ELT283	A Solid State Technology Enabled Compact, Modular Design to Reduce DC Fast Charging Cost and Footprint†	Vijay Bhavaraju (Eaton)	2-96	2.67	2.83	3.33	2.83	2.85
ELT284	Ultra-low Cost, All-SiC Modular Power Converters for DC Fast Charging Equipment Connected Directly to Medium Voltage Distribution System	Srdjan Lukic (North Carolina State University)	2-99	3.50	3.50	3.50	3.33	3.48
ELT285	Development and Demonstration of Zero-Emission Technologies for Commercial Fleets (Supertruck 3)	Maarten Meijer (PACCAR)	2-103	3.38	3.25	3.50	3.25	3.31
ELT286	A Zero Emission Freight Future (SuperTruck 3)	Eric Bond (Volvo)	2-107	3.17	2.83	2.67	3.17	2.94
ELT287	Cummins High Power Density Inverter	Santhosh Krishnamoorthi (Cummins)	2-110	3.75	3.50	3.63	3.13	3.53
ELT288	Scalable Ultra Power-Dense Extended Range (SUPER) Inverter	Harsha Nanjundaswamy (Borg Warner)	2-113	3.33	3.00	3.17	3.17	3.13
ELT290	Behind-the-Meter-Storage	Matthew Keyser (National Renewable Energy Laboratory)	2-116	3.17	3.33	3.17	3.00	3.23
ELT291	Enabling Extreme Fast Charging with Energy Storage	Jonathan Kimball (Missouri University S&T)	2-119	3.83	3.67	3.50	3.33	3.65
Overall Average				**3.28**	**3.25**	**3.17**	**3.11**	**3.23**

† Denotes poster presentation.

Presentation Number: ELT158
Presentation Title: Zero-Emission Cargo Transport II, San Pedro Bay Ports Hybrid & Fuel-Cell Electric Vehicle Project
Principal Investigator: Seungbum Ha (South Coast Air Quality Management District)

Presenter

Seungbum Ha, South Coast Air Quality Management District

Reviewer Sample Size

A total of 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.

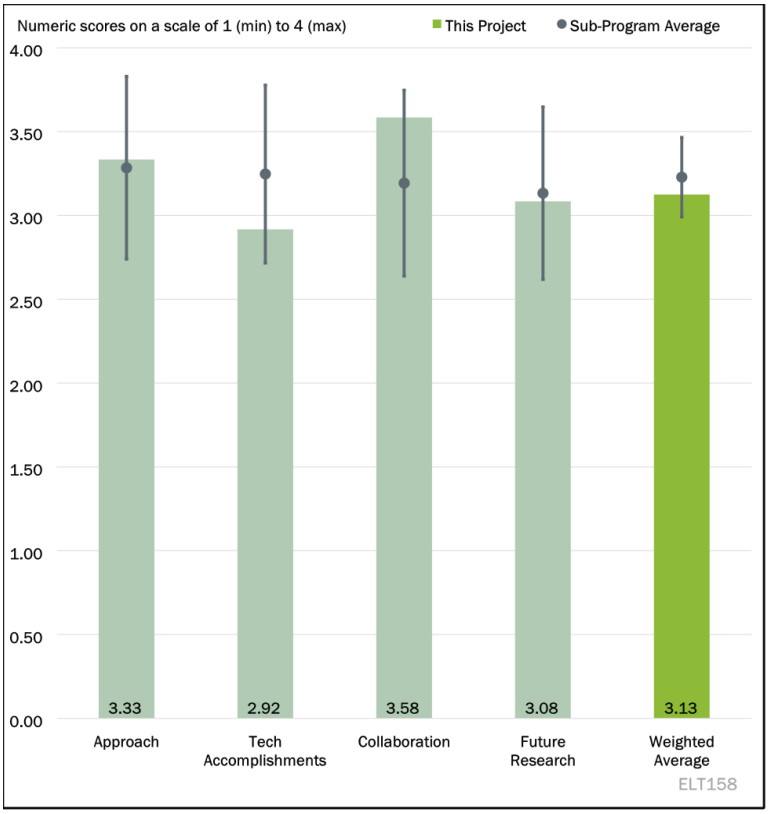

Figure 2-1 - Presentation Number: ELT158 Presentation Title: Zero-Emission Cargo Transport II, San Pedro Bay Ports Hybrid & Fuel-Cell Electric Vehicle Project Principal Investigator: Seungbum Ha (South Coast Air Quality Management District)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that this 10-year project is close to completion of both goals outlined in the presentation: development of Cummins fuel cell electric vehicle (FCEV) truck, and the development of the commercialization roadmap. The reviewer added that the team members have the distinction of demonstrating the first fleet of FCEVs for drayage use in California. The reviewer mentioned that the project recognizes the barriers to adoption of this technology by drayage companies once fully developed and embraced by original equipment manufacturers (OEMs)—the most prevalent at this juncture being cost of vehicles and availability of fueling (project used portable fueling for the demonstrations). It appeared to the reviewer from the presentation that the team will work on putting the finishing touches on the commercialization roadmap during the remainder of the project period.

Reviewer 2:

The reviewer noted that this was a 2014 proposed project (9 years ago), and that it involves a variety of truck manufacturers and component suppliers who have collaborated to develop and demonstrate seven different hydrogen fuel cell and compressed natural gas (CNG) hybrid Class 8 trucks, to meet the specific duty cycle needs of the San Pedro Bay port drayage fleet in California's South Coast air basin. The reviewer indicated that the approach could be strengthened by involving additional large traditional truck OEMs but said that 9

years ago none of them were likely seriously considering fuel cell powertrains, and that project funding was not significant enough to entice their participation.

Reviewer 3:

The reviewer expressed that this project does a good job at addressing key barriers including system integration and fueling infrastructure.

Reviewer 4:

The reviewer commented that the barriers and technical challenges identified included availability and location of fueling infrastructure; costs of fuel cells, batteries, and infrastructure; and system integration to achieve safe and efficient deployment of the technologies developed. The reviewer noted that, according to the presenter, this project was initiated in December 2015 and has been funded a total of $20.5 million from all sources since then, so the timeline is reasonable to address all the barriers and challenges. The reviewer stated that the approach was to develop a series of fuel cell vehicles that would achieve increasing travel distances from 100 miles to as much as 500 miles using seven types of hybrid and fuel cell vehicles manufactured by six different OEMs. The reviewer added that this mix of vehicles and manufacturers evaluated over a 7-year period certainly allows for a well-designed project with an extensive but reasonable timeline for research and development, which is typically three to 5 years. The reviewer stated that the project efforts included an in-use demonstration and vehicle performance analysis, followed by a total cost of ownership (TCO) analysis and development of a commercialization roadmap. The reviewer confirmed that this approach supports a successful development effort from laboratory scale proof of concept to market-readiness and proof of commercialization.

Reviewer 5:

The reviewer had a hard time trying to figure out what the goals, objective, and targets for the project are. The reviewer explained that they are different for zero emission cargo transport (ZECT) I and ZECT II, and that there are so many different variations in the fuel cell trucks—platform, fuel cell capacity, battery capacity, and range—that the purpose of testing all these variables is not clear. The reviewer expressed confusion over why CNG is even included in this project because CNG is already a clearly proven and undoubtedly adopted technology. The reviewer remarked that there was no chart in the presentation on the causes of breakdown in the fuel cell or fuel system, but that the presenter was able to generally describe them. The reviewer suggested that this should be well documented if the goal is commercialization, so that all the problems in the fuel cell stacks for the different manufacturers can be fixed before they are commercialized. The reviewer added that the principal investigator needs to set thresholds for levels of acceptance, technology readiness, or market readiness and durability acceptability as well as technical specifications for what constitutes proof of product or proof of technology. The reviewer said that otherwise, everything is just smoke and mirrors.

Reviewer 6:

The reviewer remarked that this project focuses on the vehicle use case evaluation, but that the hydrogen (H_2) fueling infrastructure is still a large challenge that needs to be addressed.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated that vehicles were successfully put in operation and data were collected. The reviewer noted that in the eight months left in this project, the team will work on putting the finishing touches on the commercialization roadmap.

Reviewer 2:

The reviewer remarked that good progress has been made to develop and demonstrate six different zero-emission and one hybrid CNG near-zero-emission truck technologies. The reviewer added that the role of hydrogen and CNG hybrid trucks has been documented in the commercialization roadmap where, because of their quick refueling capability, they are an alternative option to battery electric trucks for routes beyond 200 miles. The reviewer expressed that California's mandate for 100% zero-emission drayage trucks by 2035 is a significant driver, and this project has provided a good platform for supporting zero-emission technology development beyond battery electric trucks. The reviewer concluded that this project has provided large strides in technology readiness level (TRL) on overall vehicle design and architecture, and that it has resulted in improvements to packaging and vehicle control strategies to increase efficiency.

Reviewer 3:

The reviewer said that having six demonstration trucks on the ground shows good progress, but more hours are needed.

Reviewer 4:

The reviewer noted that the current effort for this project is to evaluate vehicle in-service operation of a fuel cell truck used for transporting goods. The reviewer remarked that this involved deployment of the vehicles on a regularly schedule route between Long Beach, California, Los Angeles, California, and San Bernardino areas with quick fueling along the route. The reviewer added that sufficient trips were assessed to equate to a 200-mile service area. The reviewer stated that a performance analysis was conducted to compare fuel cell versus battery vehicles within ranges of 150 miles to 500 miles to detect any overall trends, and to spot days of service that would be specific to the vehicles used by the trucking company. The reviewer expressed that this in-use demonstration and vehicle performance analysis for a fuel cell HD vehicle is important to not only the trucking company but also to DOE in the areas of fuel cells and electrification, to assess how the range and refueling times of these vehicles can be improved. The reviewer remarked that this project also produced a commercialization roadmap that compared key performance metrics for diesel, compressed natural gas, hydrogen fuel cell, and battery electric HD trucks which will help define the role of hydrogen fuel cells and compressed natural gas trucks for future applications. The reviewer indicated that the data gathered for the roadmap will assist fuel cell powertrain manufactures toward their commercialization efforts for their technologies. The reviewer noted that for this evaluation, the average number of stops per day was higher for the fuel cell trucks than for conventional trucks; however, the average fuel economy was higher. The reviewer concluded that the technical progress over the past year clearly supported the project plan and produced significant findings for HD fuel cell vehicles in a real-world environment.

Reviewer 5:

The reviewer stated that without a set of established milestones, it is impossible to evaluate technical accomplishments and progress. The reviewer added that if there is a set of milestones, then the principal investigator failed to include it in his presentation.

Reviewer 6:

The reviewer declared that the status and progress are unclear of the "development of the Cummins [fuel cell electric truck] FCET." The reviewer added that the design specs are provided, and the commercialization roadmap is detailed, but the progress of the truck development is not clear. The reviewer remarked that for the six deployed trucks, there is little information provided on the results analysis of the deployment in terms of fuel consumption, efficiency, reliability (service or repair), total miles driven, range impact by load or mass, ambient temperature, road conditions or terrain, powertrain performance comparison, etc.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer commented that the presentation file references five "contractors and projects," and it is unclear if these are participants or team partners. The reviewer added that it appears at the very least, that all or most were enthusiastic participants.

Reviewer 2:

The reviewer remarked that there was a good variety of project participants, including large truck and drivetrain OEMs. The reviewer added that OEM participation could be strengthened based on today's developments; however, it is important to note that this project was proposed in 2014. The reviewer noted that National Renewable Energy Laboratory (NREL) participation for data collection and analysis adds experienced 3rd party credibility.

Reviewer 3:

The reviewer stated that the diversity of partners and funding is excellent.

Reviewer 4:

The reviewer commented that the collaboration involved a state government agency, four manufacturers of fuel cells, one manufacturer of compressed natural gas hybrid powertrains, and a national laboratory. The reviewer expressed that for the type of data needed for this project and for preparing a commercialization roadmap, this is considered to be an outstanding collaboration team.

Reviewer 5:

The reviewer liked the inclusion of Total Transportation Services, Inc. (TTSI), as an operator to demonstrate the fuel cell trucks. The reviewer has worked with TTSI before and thought they were very open-minded to trying out new technology.

Reviewer 6:

The reviewer acknowledged that several truck manufacturers are listed under "Contractors & Projects." It appeared to the reviewer that six trucks are deployed with a seventh truck under development. The reviewer suggested that the project team considers collaboration with H_2 fueling infrastructure partners to address remaining challenges.

Question 4: Please comment on the 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 this project was created with the expectation that there would be a need for future research and holds future promise for the manufacture of zero- or near-zero-emission vehicles for drayage use. The reviewer noted that Slide 16 clearly lists steps of future research.

Reviewer 2:

The reviewer expressed that future research includes continued in-use demonstration data collection, the TCO analysis, and commercialization roadmap which all seem appropriate. The reviewer suggested that input from traditional truck OEMs such as Freightliner, International, and Volvo, in addition to Kenworth and Cummins, would be important to strengthen the commercialization roadmap for fuel cell trucks beyond the perspectives of the project partners. The reviewer observed that TCO analysis should include fuel cost and driveline efficiency, as well as truck cost sensitivity analysis as the range of fuel prices depending on location can vary

significantly (i.e., H_2 from $6/kg to $30/kg H_2 and electricity from $0.10/kWh to $0.50/kWh based on current hydrogen and electric truck deployments).

Reviewer 3:

The reviewer said that it will be telling if the project is able to secure regular fuel supply for this project to take steps toward market transformation.

Reviewer 4:

The reviewer remarked that proposed future research includes continuing the HD fuel cell truck demonstration to collect realistic operational data for the average vehicle miles traveled and the fuel economy, analyzing the TCO for the vehicle, fuel, and maintenance costs to also include infrastructure cost and assessment of time and weight penalties, and revising the commercialization roadmap to provide a better market development strategy and accelerate participation by original equipment manufacturers. The reviewer asserted that this is considered an excellent approach to collect and use as much information as possible in the final year of the project.

Reviewer 5:

The reviewer was unsure if this project is ready for analyzing the TCO until there is some confidence that all the problems in the fuel cell system are fixed, and until some level of technology readiness or market readiness has been achieved, and there is objective data showing that proof of product or proof of technology has been attained.

Reviewer 6:

The reviewer indicated that the portion of future research, "Collect real operation data from demonstration," would have been more effective over the prior 24 months of deployment rather than starting in the final Budget Period. The reviewer added that analysis of TCO and the commercialization roadmap are important areas of future research. The reviewer stated that H_2 fueling infrastructure should be considering for future research due to numerous challenges.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer remarked that this project most notably supports the VTO subprogram goals for Decarbonization of Off-road, Rail, Marine and Aviation (DORMA), Analysis, and Electrification. The reviewer stated that the California Air Resources Board (CARB) mandates and VTO objectives often coincide, and historically, port operations produce pollution, particularly in marginalized neighborhoods. The reviewer noted that this project represents a big step to rectify that.

Reviewer 2:

The reviewer observed that the project is relevant to the VTO Electrification subprogram as it is pushing zero-emission technology and industry envelope by demonstrating first fleet of fuel cell electric trucks in California's drayage service.

Reviewer 3:

The reviewer confirmed that it is a helpful evaluation of technologies, including electric. The reviewer added that the commercialization roadmap will be of interest to VTO and other DOE transportation programs.

Reviewer 4:

The reviewer expressed that this demonstration project fully supports the Batteries and Electrification R&D Program Office Grid and Charging Infrastructure program's mission to conduct early-stage research and

development on transportation electrification technologies that enable reduced petroleum consumption by light-, medium-, and HD vehicles albeit for fuel cell vehicles and not EVs specifically.

Reviewer 5:

The reviewer wished the project could come up with some data to show that it is worthwhile paying for a fuel cell truck-tractor that costs four times that of a conventional diesel truck-tractor.

Reviewer 6:

The reviewer stated that this project supports the VTO objectives by improving HD transportation efficiency and emissions reduction.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer mentioned that the resources allocated appear sufficient and reasonable. The reviewer stated that there will undoubtedly be a need for additional resources for projects dedicated to advancing this technology.

Reviewer 2:

The reviewer noted that the significant project budget of $20 million with DOE contributing 50% was needed to develop and demonstrate seven prototype fuel cell and hybrid trucks from scratch. The reviewer added that the project completion date in 2024 will make this more than a 9-year project due to a variety of barriers faced but will provide 2 years of in-use data on each technology. The reviewer concluded that while additional budget would likely not significantly accelerate the project, it could have potentially attracted increased participation of more truck OEMs.

Reviewer 3:

The reviewer stated that costs will be challenging. The reviewer explained that while it is difficult to determine if funds will be sufficient, effort should be made to stay within cost parameters.

Reviewer 4:

The reviewer acknowledged that this project is funded $20.5 million over a 9-year period which is an average of $2.3 million per year, of which half is funded by DOE. The reviewer considered this to be sufficient funding for a demonstration project that will reap benefits for future fuel cell development.

Reviewer 5:

The reviewer had no access to costs of materials and labor to conduct a project of this nature.

Reviewer 6:

The reviewer commented that resources are sufficient for this multi-year, HD vehicle demonstration.

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 and Manufacturing)

Presenter

David Crecelius, American Axle and Manufacturing

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.

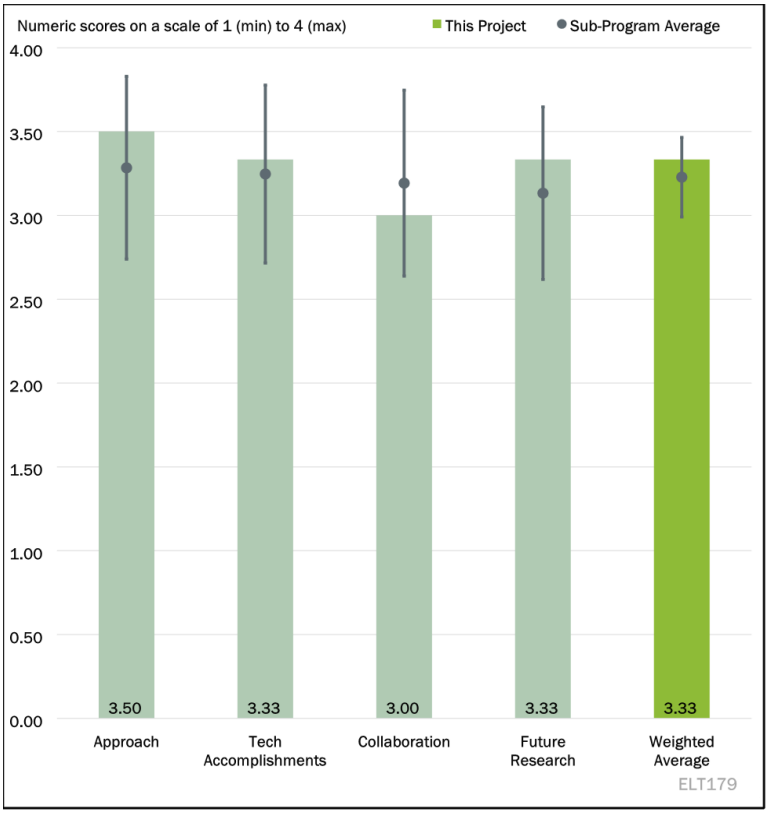

Figure 2-2 - Presentation Number: ELT179 Presentation Title: Low Cost, High-Performance, Heavy Rare-Earth-Free 3-In-1 Electric Drive Unit Principal Investigator: David Crecelius (American Axle and Manufacturing)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer said that the technical barriers are nicely documented and transparently addressed.

Reviewer 2:

The reviewer remarked that American Axle and Manufacturing (AAM) has done an outstanding job addressing the technical barriers. The reviewer added that AAM has been very professional in their approach and execution of this project.

Reviewer 3:

The reviewer indicated that the core idea of a high-speed induction motor with copper rotor bars is not novel. The reviewer added that the mass, volume, and efficiency of the gearbox should be factored in the predicted system performance. The reviewer noted that some detailed cost comparison of the induction motor with copper rotor bars versus a permanent magnet (PM) counterpart should be provided.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer indicated that the project appears to be on track with all the promised deliverables met.

Reviewer 2:

The reviewer stated that AAM has made excellent technical progress. The reviewer highlighted that when they had difficulty with the silver sintering, they quickly moved to copper sintering.

Reviewer 3:

The reviewer noted that there is no thermal analysis or measurements presented to show the predicted system thermal performance. The reviewer remarked that no mechanical analysis or rotor spin test was presented to prove the structural integrity of the high-speed motor. The reviewer suggested that more information and analysis regarding the integration details of the motor and inverter should be provided. The reviewer asked if, with the inverter tightly integrated with the motor, there are any vibration or thermal issues expected.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer stated that clear leadership is evident, which drives results. The reviewer added that in other projects some collaborators appear to be pro-forma, without a major contribution, so the reviewer did not mind the lack of laboratories of universities as collaborators.

Reviewer 2:

The reviewer confirmed that AAM appears to have assembled an excellent team, each member with their own strengths.

Reviewer 3:

It seemed to the reviewer that the main bulk of the project is really done within the primary recipient.

Question 4: Please comment on the 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 is on track, clearly defined, and documented. The reviewer was looking forward to next year.

Reviewer 2:

The reviewer noted that future work is directly in line with the original plan and is very well executed.

Reviewer 3:

The reviewer remarked that ultimately testing the full system will be helpful, but some of the intermediate analysis and testing referred to should be considered.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer noted that in the Electrification (subprogram), this is one of the top projects.

Reviewer 2:

The reviewer remarked that the “Relevance” slide in this presentation is one of the best from the Annual Merit Review (AMR) and stressed that it was outstanding.

Reviewer 3:

The reviewer expressed that the project tries to eliminate RE material and to come up with a lower cost, more compact and integrated electric drivetrain.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the cost appears to be sufficient and well tracked.

Reviewer 2:

The reviewer noted that the resources for this project have been well spent.

Reviewer 3:

The reviewer affirmed that the resources are sufficient for the scope.

Presentation Number: ELT197
Presentation Title: High Power and Dynamic Wireless Charging of Electric Vehicles
Principal Investigator: Veda Galigekere (Oak Ridge National Laboratory)

Presenter

Veda Galigekere, Oak Ridge National Laboratory

Reviewer Sample Size

A total of 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.

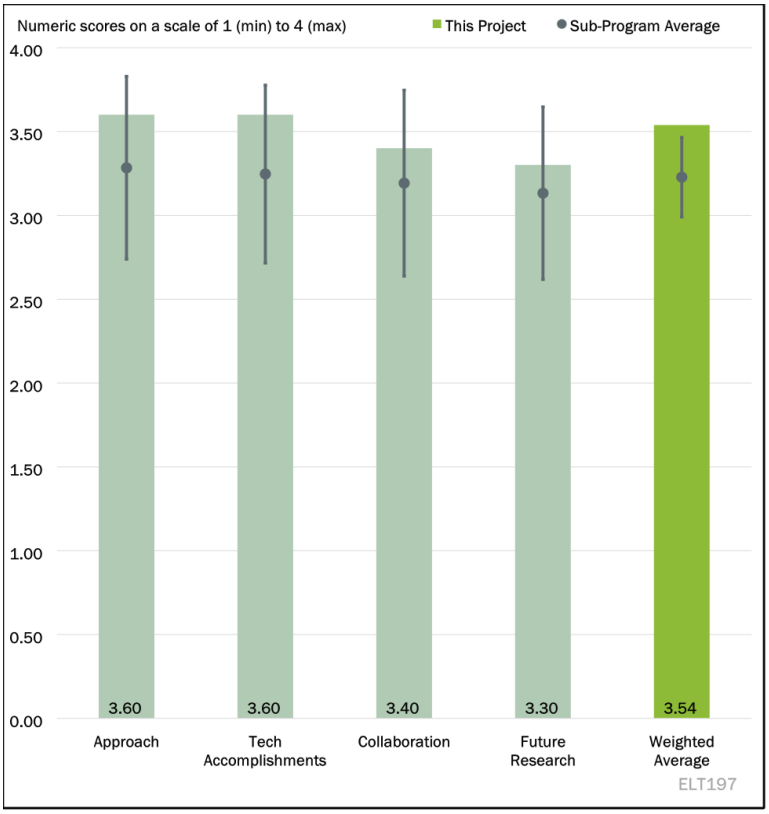

Figure 2-3 - Presentation Number: ELT197 Presentation Title: High Power and Dynamic Wireless Charging of Electric Vehicles Principal Investigator: Veda Galigekere (Oak Ridge National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer observed that this Oak Ridge National Laboratory (ORNL) led project's workflow is logical and as per engineering practices because analytical and simulation works feed data requirements for hardware development, followed by laboratory validation of the 200 kW dynamic wireless power transfer (DWPT) system, which will lead to real world validation at 200 kW level. The reviewer added that the project report has included some pictures of the parts that would be required in the development of a prototype of the proposed DWPT.

Reviewer 2:

The reviewer noted that the project targets full-scale demonstrations of wireless charging technology. The reviewer remarked that the program also includes laboratory and road validation of the technology, including intermediate check points and design reviews. The reviewer concluded that the approach is rational and sound.

Reviewer 3:

The reviewer commented that the approach is excellent—starting with laboratory development and testing and then moving to the demonstration of the system installed in a roadway with vehicle testing. The reviewer noted that various vehicle speeds are also considered which applies to match the application into production vehicles with the power level required.

Reviewer 4:

The reviewer remarked that three challenges were identified as barriers to high power and dynamic wireless charging of EVs: power density, efficiency; and controllability. Regarding power density, the reviewer referenced development of a compact vehicle coil and power electronics assembly which can receive 200 kW power dynamically. Concerning efficiency, the reviewer noted achieving 90% efficiency in a vehicle integrated dynamic wireless charging system. And with controllability the reviewer referenced identifying and implementing a control and communication system which can perform wide range power regulation without compromising efficiency or power density. The reviewer mentioned that the approach to complete the proof-of-concept validation included analytical and simulation studies; hardware design and development; laboratory validation of 200 kW dynamic wireless power transfer; and real-world validation of 200 kW DWPT.

Reviewer 5:

The reviewer observed that the project is well-designed covering all aspects of dynamic charging in light-duty and HD vehicles. The reviewer added that hardware development along with laboratory and real-world validation captures all the aspects of dynamic charging. The reviewer said that dynamic inductive charging is operational and will be used to perform controlled dynamic charging tests to optimize control and efficiency.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated that baseline performance was established in stationary mode. The reviewer remarked that the 200 kW DWPT system with receiver coil was mounted on a Hyundai Kona. The reviewer observed that the project team validated power transfer capability in dynamic mode, including capturing waveforms to assess peak magnitude of the output power during DWPT operating mode of the system. The reviewer said that a list test of transmitter coil buried in concrete slab was carried out, along with a preliminary review of structural design. The reviewer noted that the status of high power DWPT system validation in the American Center for Mobility (ACM) is described in the project's AMR report, the DWPT data acquisition system was completed, and the operational functionality was verified.

Reviewer 2:

The reviewer noted that significant progress has been made on the program. The reviewer stated that design and hardware validation has been demonstrated for laboratory conditions. The reviewer reported that ongoing work seeks to validate at relevant driving speeds and for on-road conditions. The reviewer indicated that several milestones listed for 2022 were identified as planned or in progress, but questioned if perhaps there was an error in the dates as these efforts are now ongoing. If not, then the reviewer concluded that the project is delayed by approximately 1 year.

Reviewer 3:

The reviewer stated that the laboratory tests are conducted at reasonable speeds to capture lower vehicle speeds, and that track testing will capture the higher speeds projected for the system.

Reviewer 4:

The reviewer observed that the project team members validated stationary power transfer at an efficiency of 93.7% with no thermal hotspots. The reviewer added that validation of power transfer capability in dynamic mode was then completed at 6 meters per second (13 miles per hour). The reviewer added that the test rig has the capability to test up to 9 m/s (20 mph) over the track length of 18 meters. The reviewer noted that the in-ground transmitter structure was assessed, and it was determined that the surface cracks which occurred during setting and curing did not propagate, and that no buckling or deflections were observed. The reviewer said that DWPT data acquisition system for ground side and vehicle side measurements were completed, and the

operational functionality was verified using a production EV with a Nissan Leaf. The reviewer indicated that a final demonstration is still pending, and real-world validation is ongoing.

Reviewer 5:

The reviewer noted that the project team completed high-level cost and feasibility studies and identified the architecture suitable for 200 kW DWPT. The reviewer added that the team completed design, development, and laboratory benchtop validation of primary and secondary side power electronics design of 200 kW DWPT system. The reviewer indicated that the team completed design, development, and validation of DWPT coils and tuning network. The reviewer observed that the team is identifying and developing active and passive electromagnetic field shielding solutions for 200 kW DWPT system. The reviewer stated that the team analyzed feasibility of large-scale deployment of DWPT system on primary roadways in Atlanta; developed E-Roads Tool for analyzing large-scale deployment of DWPT system on roadways; and completed laboratory validation of 200 kW DWPT system.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer noted that an excellent collaboration exists in execution of project activities.

Reviewer 2:

The reviewer stated that the majority of work is centralized at ORNL, with input and support from other partners. The reviewer added that engagement external to the laboratory is beginning.

Reviewer 3:

The reviewer indicated that system approaches are excellent with support from other laboratories, and that these are complementing the project with electromagnetic compatibility/electromagnetic fields (EMC/EMF) evaluation and multiple vehicle designs.

Reviewer 4:

The reviewer observed a good balance between national laboratory participation (ORNL, Idaho National Laboratory [INL], NREL), vehicle OEM (Hyundai Kia American Technical Center), test facility (American Center for Mobility) and a university research institute (Virginia Tech Transportation Institute). The reviewer added that this project will impact utilities, and a national utility organization should be added to the team as this system moves toward commercialization.

Reviewer 5:

The reviewer acknowledged that Hyundai America Technical Center, Inc., (HATCI) is providing an EV, as well as support and guidance on vehicle-integration of DWPT system. The reviewer added that ACM is providing infrastructure and physical proving grounds for validation of 200 kW DWPT system. The reviewer said that Virginia Tech Transportation Institute (VTTI) is providing guidance and support to develop roadworthy DWPT coils. The reviewer concluded that all of the collaboration was well planned and executed and produced valid results.

Question 4: Please comment on the 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 report included future research task and topics, which are relevant and appropriate.

Reviewer 2:

The reviewer mentioned that the project work is nearing completion. The reviewer noted that future work suggestions include developing specifications documents as well as lessons learned from the project that may help inform both future research at the system level, but also the component and even subcomponent level. The reviewer asked what the key limiting factors and technologies currently are.

Reviewer 3:

The reviewer observed that alternatives of primary coil could be useful to reduce installing magnetics in the roadways, and that higher power may also be offered for larger vehicle applications.

Reviewer 4:

The reviewer said that this project is coming to an end. The reviewer indicated that the characteristics that will be assessed through planned future research include: efficiency, power, and energy profiles; safety misalignment tolerance; thermal profiles; emissions and shielding; interoperability; and environmental factors. The reviewer added that the high power DWPT system validation is planned for demonstration at 55 mph in the summer of 2023 at the ACM, and that integrating the passive electromagnetic-field shielding solution developed by INL with the 200 kW DWPT system developed by ORNL is also planned to be completed.

Reviewer 5:

The reviewer indicated that the project validates performance and functionality of 200 kW DWPT system, and analyzes the power transfer characteristics including: efficiency, power, and energy profiles; safety misalignment tolerance; thermal profiles; emissions and shielding; interoperability; and environmental factors.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that this project is relevant to the VTO electrification subprogram and will accelerate adoption of EVs as battery size could go down and cost target could be met for many Americans.

Reviewer 2:

The reviewer noted that the project is highly relevant to future EV charging infrastructure.

Reviewer 3:

The reviewer observed that vehicles using dynamic wireless charging offer a means to provide the propulsion energy and some recharging of the high voltage (HV) battery while traveling. The reviewer explained that this offers opportunity for lower capacity HV batteries and less time and energy for charging at alternating current (AC) and direct current (DC) charging locations.

Reviewer 4:

The reviewer said that the project is directly relevant to the VTO Materials subprogram objectives.

Reviewer 5:

The reviewer commented that validating high power and dynamic wireless charging of EVs is essential to move transportation to zero tail pipe emission technologies. The reviewer added that charging locations and time to charge is a very large issue not resolved in EV deployments worldwide.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that the project has necessary resources and research funds.

Reviewer 2:

The reviewer stated that overall, the project seems to be successful, but the challenge and complexity of the problem being addressed could benefit from additional resources in this area.

Reviewer 3:

The reviewer observed that this project has managed resources of other laboratories, vehicles, and test sites to maintain the full spectrum of effort required.

Reviewer 4:

The reviewer indicated that the resources appear to be sufficient to achieve the stated goals of the project.

Reviewer 5:

The reviewer affirmed that the project has all the resources required to this point. The reviewer said that any further research will require end user transportation professionals as part of the team. The reviewer added that these end users will need to be fleets with internal engineering capability to ensure the project is on pace to be business friendly, cost effective, and reliable to industry.

Presentation Number: ELT208
Presentation Title: Highly Integrated Power Module
Principal Investigator: Lincoln Xue (Oak Ridge National Laboratory)

Presenter

Lincoln Xue, Oak Ridge National 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 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.

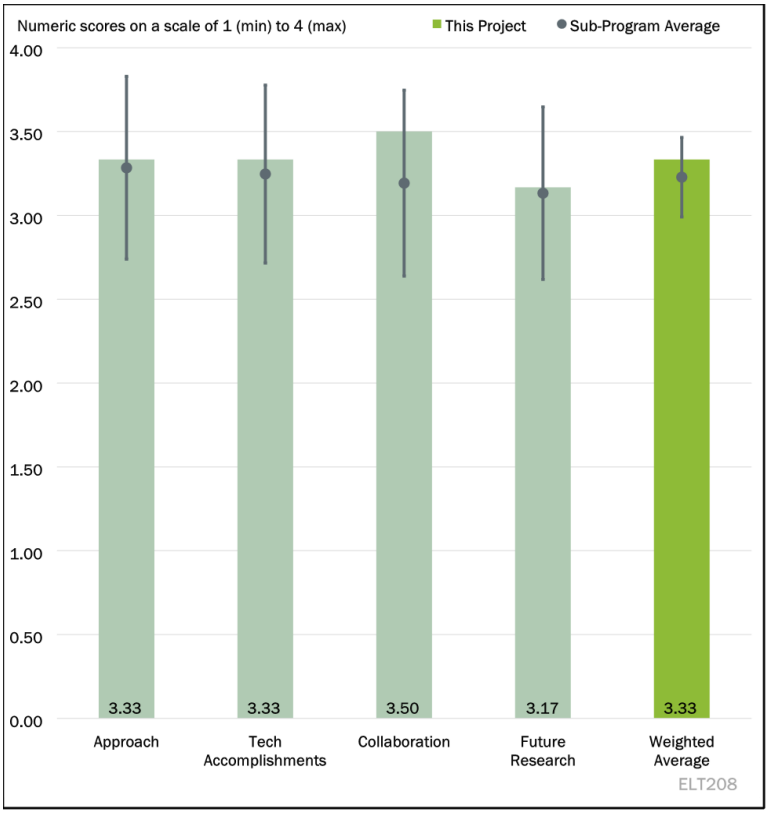

Figure 2-4 - Presentation Number: ELT208 Presentation Title: Highly Integrated Power Module Principal Investigator: Lincoln Xue (Oak Ridge National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that project activities are for automated power module design which uses a new analysis method that is a computationally efficient method for optimized layout including base-place and cold plate associated with power module of power converters. The reviewer added that having many designs and then down selecting the optimal design is an appropriate approach for the power module design.

Reviewer 2:

The reviewer remarked that the proposed work combines targeted experiments with modeling and optimization. The reviewer said that the work plan is sound and clearly aligns with targeted improvements to technical challenges relevant for highly integrated power modules, with emphasis on thermal performance. The reviewer recommended that additional work should be placed upon isolation requirements.

Reviewer 3:

The reviewer mentioned that there was a design and prototype of organic direct bonded copper (ODBC) based power modules with integrated gate driver and cooling to enhance thermal performance.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that key activities that are completed by the project team and are likely to set this project for the successful completion include and details of work underwent for these tasks is outlined in the project report. The reviewer explained that the team designed a silicone carbide (SiC) power module based on a thermal pyritic graphite (TPG)-ODBC substrate, integrated gate driver, and heat sink; prototyped the ODBC-based power module; evaluated electrical performance of the Cu-ODBC power module; fabricated multiple substrate samples for breakdown evaluation; completed thermal evaluation with the Cu-ODBC power module; developed a simulation framework of indirect and direct substrate cooling for wide bandgap (WBG) power modules; designed high-performance direct cooling of power modules based on optimized jet impingement structures; completed thermal-mechanical analysis on direct substrate cooling; invented a new heat sink geometry generation method; generated genetic algorithm optimized heat sink designs using a multi-profile merging method; simulated the thermal performance of the selected new heat sink design; and discovered mechanisms of better performance for the multi-profile merging method.

Reviewer 2:

The reviewer remarked that the project has made significant progress towards the targeted goals, and that there are currently no indications of a deficiency in technical performance.

Reviewer 3:

The reviewer noted the prototyping and evaluation of electrical performance.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer observed that a strong collaboration exists in execution of project activities.

Reviewer 2:

The reviewer remarked that the work appears largely centralized at ORNL. The reviewer added that if substantive contributions are being made by partners, it is not clearly represented within the peer review slides. The reviewer suggested clearly identifying partner contributions where appropriate in future updates.

Reviewer 3:

The reviewer noted a good combination of partners that includes laboratories, industry as well as academic research.

Question 4: Please comment on the 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 has outlined future research. The reviewer observed that it would be nice if material saving, and carbon footprint reduction are also assessed due to technique developed in this project. The reviewer added that the profiled heatsink will require a far complex fabrication process, and the aspect of how that would impact adoption of such a heat sink in real world applications needs some research efforts.

Reviewer 2:

The reviewer noted that isolation should be a primary consideration for future work. The reviewer added that the future work should clearly focus on practical embodiments of the proposed advanced cooling designs which are both reproducible and scalable in terms of manufacturability.

Reviewer 3:

The reviewer remarked system integration and evaluation.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that this project is relevant to VTO sub-program in electrification area and could fulfill keystone projects' objectives.

Reviewer 2:

The reviewer said that this program has clear relevance.

Reviewer 3:

The reviewer noted that the project is relevant to all defined targets: Power density at 100 kW/L; cost at $2.70/kW; peak efficiency at greater than 97%; and reliability at 300,000 mile lifetime or fifteen years.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that the project has necessary resources and research funds.

Reviewer 2:

The reviewer said that resources appear to be appropriate for the proposed work scope.

Reviewer 3:

The reviewer remarked that the design for manufacturing has a great deal of input by industry yet to be observed.

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, 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.

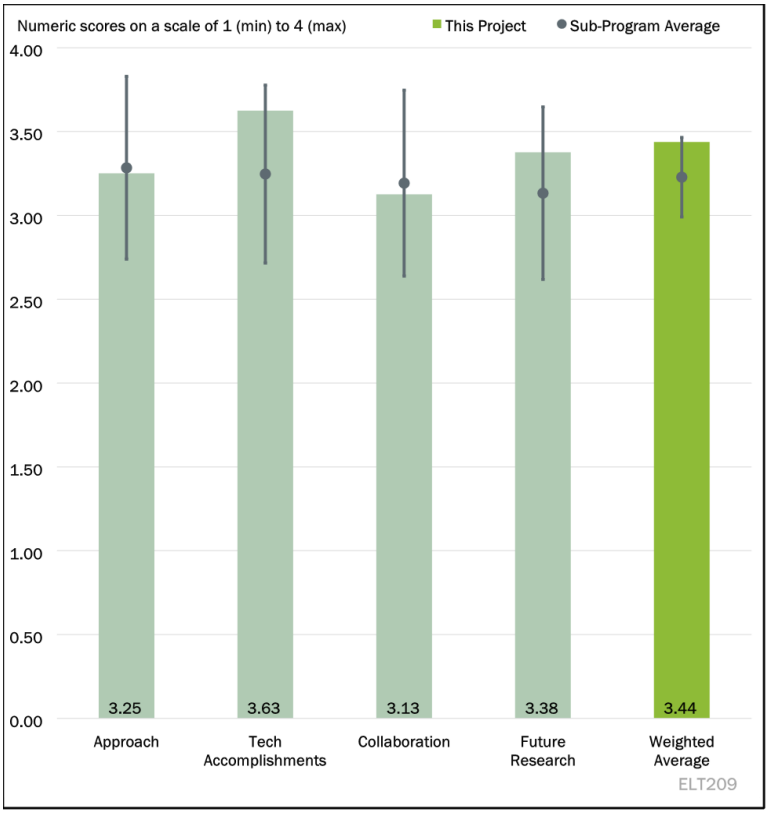

Figure 2-5 - Presentation Number: ELT209 Presentation Title: High-Voltage, High-Power Density Traction-Drive Inverter Principal Investigator: Gui-Jia Su (Oak Ridge National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer said that the project addresses a segmented inverter, which has the potential to significantly decrease capacitor ripple current for improved reliability and performance. The reviewer noted that the project team is using advanced devices and packaging to enable higher DC bus voltage. The reviewer's only minor critique is that the need for an asymmetrical six-phase inverter—with 30^{o} phase shift—is not fully explained. The reviewer added that the sophisticated packaging and overall architecture are the focus of the project and are appropriate to address the objectives.

Reviewer 2:

The reviewer stated that the approach to the design of the segmented inverter is interesting and different and seems technically capable. The reviewer noted that the assessment of reliability and practicality in terms of cost—both related to total amount of semiconductor needed for the segmented circuit topology—seems lacking overall. The reviewer added that the approach would benefit greatly from a techno-economic analysis that considered these factors and made an assessment of the cost and reliability impacts. The reviewer shared, as a general comment, that the cooling solution and power card-like structure plus module packaging is very similar to Denso's design, regardless of the heat sink fin optimization and three-dimensional (3D) printing of manifold, so the reviewer questioned if the novelty really is just the segmented topology or some other aspect.

Reviewer 3:

The reviewer noted the well-defined inverter architecture to reduce capacitor requirement, as well as the operating bus voltage of more than 800V.

Reviewer 4:

The reviewer remarked that the project does address the issue of reducing the space claim of large capacitances and also maintains high efficiency. The reviewer added that it would be interesting to see a trade-off between this approach and using higher switching frequency to achieve the same goals. The reviewer explained that while the general trends with the two approaches are clear, it would be good to quantify these differences. The reviewer stated that different hat sink designs are interesting, but it is unclear what impact the manufacturing processes would have for volume production.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer observed that the team has made excellent progress on two different packaging approaches. The reviewer noted that the team has developed an inverter control system; completed a 100 kW inverter with excellent efficiency; has a 200 kW inverter designed, including an optimized heat sink, as well as parts of a Gen-2 200 kW system. The reviewer suggested that the team investigates the suitability of the thermistor isolation, as its physical separation may be adequate for prototypes but not for products.

Reviewer 2:

The reviewer noted that significant accomplishments are demonstrated related to the 100 kW and 200 kW inverter designs, fabrication, and test, and offered that testing at higher power levels should be accelerated.

Reviewer 3:

The reviewer remarked that the efficiency at 100 kW load for Gen 1 inverter design has not been reported.

Reviewer 4:

The reviewer declared that while the Gen 1 appears to have fallen short of the power density goals, the Gen 2 inverter appears to be on track to meet the goals. The reviewer added that a significant reduction in ripple current has also been shown. The reviewer said that it is also good that, unlike some other projects, this project is working with a DC bus voltage of 800V instead of 400V, since given the power of most EVs that are being sold/will be sold in the United State, and due to fast charge requirements, 400V DC bus will likely be phased out in favor of 800V.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer expressed concern that relates to the two apparently separate inverter developments taking place at Virginia Tech and the University of Arkansas, as they have similar goals and approaches and seem to be more in competition than in collaboration.

Reviewer 2:

The reviewer observed that there seems to be a lot of collaboration happening in the presented materials, and the table clarifies who is doing what, but it would benefit reviewers to highlight collaborator efforts on appropriate slides throughout.

Reviewer 3:

The reviewer stated that while there has been excellent cooperation between the University of Arkansas, Virginia Tech, and Oak Ridge, this project could have benefited from the involvement of an OEM or supplier—this would have helped ensure that at the conclusion of the project, there is a greater chance of this technology being implemented into production. The reviewer added that Slide 7 lists roles for Virginia Tech, University of Arkansas, and ORNL, but it is unclear throughout the presentation, what the role of NREL is in this project. The reviewer noted that it is clear that NREL has developed considerable expertise in thermal management, but it is unclear how or if that is being used in this project.

Question 4: Please comment on the 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 team proposes to finish testing the Virginia Tech design and the Gen-1 University of Arkansas design, as well as to complete the design of a Gen-2 University of Arkansas inverter. The reviewer remarked that it is unclear whether there will be a full "Gen-2" Virginia Tech design or just some improvements to the Gen-1.

Reviewer 2:

The reviewer was curious to see more information on parasitic losses of the module design and efficiency over the expected full power range.

Reviewer 3:

The reviewer declared that future plans are clearly laid out and make sense, given the outcome of the project up until now.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer noted that the project directly addresses inverter power density objectives.

Reviewer 2:

The reviewer mentioned that the project is highly relevant to electrified powertrain R&D.

Reviewer 3:

The reviewer observed that the project is relevant to all defined targets: power density at 100 kW/L; cost at $2.70/kW; peak efficiency at greater than 97%; and reliability at 300,000-mile lifetime or fifteen years.

Reviewer 4:

The reviewer stated that reducing the size or increasing the power density of every component is very important to the OEMs and suppliers, since space is always a premium. The reviewer added that with the OEMs constantly trying to increase the range, battery packs keep getting bigger and require more real estate. The reviewer commented that any space saving that can be offered up by any other components would always be welcome.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer observed that there are no obvious deficiencies, and the work seems to be scaled properly to the resources available.

Reviewer 2:

The reviewer stated that the resources are sufficient.

Reviewer 3:

The reviewer mentioned that the resources are sufficient.

Presentation Number: ELT211
Presentation Title: Power Electronics Thermal Management
Principal Investigator: Gilbert Moreno (National Renewable Energy Laboratory)

Presenter

Gilbert Moreno, National Renewable Energy Laboratory

Reviewer Sample Size

A total of 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.

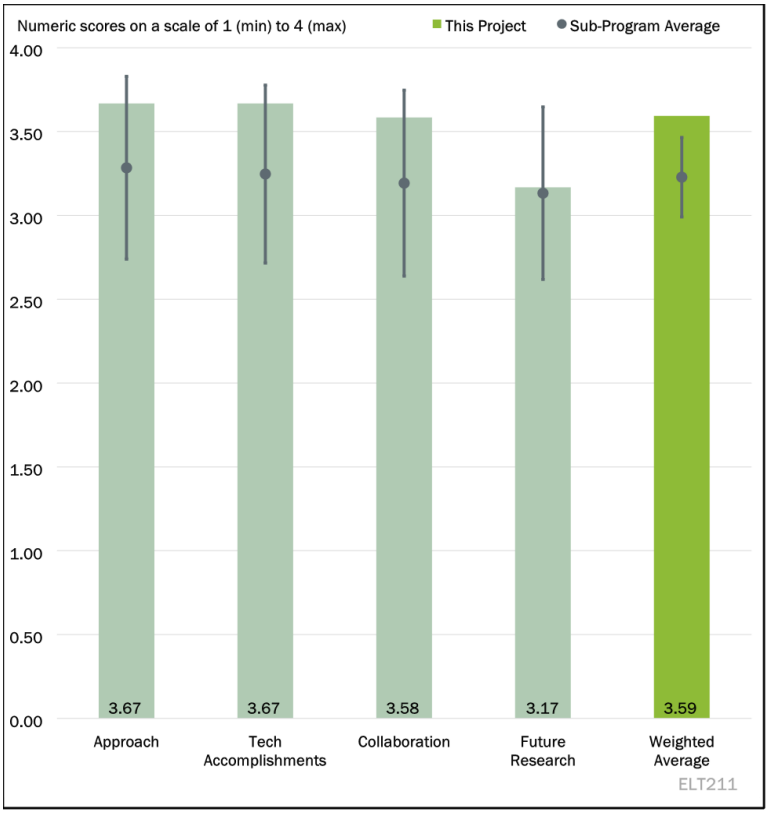

Figure 2-6 - Presentation Number: ELT211 Presentation Title: Power Electronics Thermal Management Principal Investigator: Gilbert Moreno (National Renewable Energy Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that this project includes both thermal cycling and electrical performance testing to ensure that the new cooling approach effectively improves thermal performance without compromising electrical behavior.

Reviewer 2:

The reviewer noted that the comparison between conventional direct bonded copper (DBC) base power module and dielectric fluid cooled power module is an appropriate way to establish performance target for enhance cooling potentially possible with the dielectric fluid used as coolant. The reviewer added that the project principal investigator (PI) then addressed concerns associated with dielectric fluid-based colling of the power module. The reviewer noted that dialectic fluid cooled power module attempts to eliminate failure prone components such as ceramic layers while resorting to double side cooling to realize improved performance. The reviewer explained that over the temperature evaluation of the effectiveness of the dielectric fluid-based cooling should be carried out by project investigators.

Reviewer 3:

The reviewer stated that the project aims to improve the thermal management of power electronic converters to increase power density and reliability. The reviewer added that the power electronic converters can be made smaller if advanced cooling concepts can be applied. The reviewer observed that this project aligns with

achieving the year 2025 DOE 100 kW/L power density target. The reviewer noted that the approach is well-defined, and initial studies are promising for thoroughly evaluating this novel cooling scheme using a dielectric fluid with advanced packaging.

Reviewer 4:

The reviewer commented that the module cooling solution approach seems well thought out and designed. The reviewer added that both single phase and two-phase solutions have been proposed, and that the timeline seems reasonable and achievable.

Reviewer 5:

The reviewer liked that the approach specifically addresses concerns one might have with the use of dielectric fluids. The reviewer stated that the timing seems reasonable given the funding level. The reviewer would prefer to see this type of work happening at a quicker pace though.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that the project team has achieved excellent thermal performance and good model agreement. The reviewer observed that the team has provided useful comparative evaluation of several fluids to identify their relative advantages. The reviewer added that the team has started long-term thermal/electrical testing. The reviewer highlighted that the collaboration with the Georgia Tech team for two-phase cooling is a little unclear, and that presumably this is more fully explored in a separate project.

Reviewer 2:

The reviewer said that the SiC-based module fabricated and inserted in housing enabled dielectric fluid-based cooling and heat exchanger system followed by demonstration of cooling system. The reviewer stated that the test verification revealed that thermal performance evaluated by simulation and experimentation revealed similar level of capability of proposed design for the dielectric fluid-based power module cooling. The reviewer observed that the relation between fluid flow rate and power needed for dielectric fluid pumping is found as expected. The reviewer stated that the experimental apparatus was fabricated to evaluate long-term reliability of the dielectric fluid and associated heat exchanger. The reviewer said that the test apparatus realized through collaborative activities with Georgia Tech is included in the AMR report and phase change cooling has been experimented.

Reviewer 3:

The reviewer noted that the project aims to eliminate thermally resistive and failure-prone ceramic components in today's semiconductor packages. The reviewer noted that the project targets to reduce package resistance by 18%–43% by introducing a new concept. The reviewer explained that to achieve this goal, the packaging uses single-phase heat transfer. The reviewer observed that it is nice to see that project developed both single- and double-side-cooled configurations. The reviewer added that the team fabricated silicon-carbide power modules that use dielectric fluids for cooling, and that the project conducted experiments to measure the junction-to-fluid thermal resistance and pumping power. The reviewer remarked that the results are promising, and significant benefits are achieved, as illustrated in the results section of the presentation.

Reviewer 4:

The reviewer noted that the technical accomplishments are substantial and well-demonstrated through well-coordinated efforts with collaborators. The reviewer added that the high cooling performance with moderate pressure drop is achieved.

Reviewer 5:

The reviewer stated that the electric evaluation is essential to fully assess and agree to thermal evaluation benefits.

Reviewer 6:

The reviewer expressed that it was great to see the power module test setup together and under test, and that having a defined test process is excellent. The reviewer added that measurements of thermal resistance to pumping power is a key factor to gain an understanding of the performance of this method. The reviewer offered that developing an understanding of material compatibility and dielectric changes over time are critical.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer observed that it appears that the two-phase cooling subproject is integrated at the level of personnel, with a somewhat nebulous technical connection. The reviewer remarked that other team members are more clearly integrated.

Reviewer 2:

The reviewer stated that the project team has strong collaborative activities underway in a team makeup that has NREL, universities and industries.

Reviewer 3:

The reviewer mentioned that the project collaborates with Georgia Tech, Infineum, Oak Ridge National Laboratory, and the State University New York (SUNY) Polytechnic Institute. The reviewer said that it is good to see that project is collaborating with Georgia Tech to evaluate two-phase cooling strategies, and NREL designed and fabricated the experimental apparatus used for the experimental demonstration.

Reviewer 4:

The reviewer notes that the collaboration efforts were clear and substantial in the presentation.

Reviewer 5:

The reviewer remarked that it is to date and as planned.

Reviewer 6:

The reviewer observed that the number of collaboration events seems good, but it wasn't clear how much effort was being put into it.

Question 4: Please comment on the 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 team has initiated long-term testing, which by its nature will extend over the future budget periods. The reviewer stated that the team has identified some of the important challenges and ways to address them; however, the team has not really addressed the issue of contamination. The reviewer remarked that the team also identifies industry adoption as a barrier without a plan to address it.

Reviewer 2:

The reviewer commented that the project team has outlined future research. The reviewer suggested that the project team must evaluate over the temperature evaluation of the effectiveness of the dielectric fluid-based cooling system and heat exchanger including phase change cooling system.

Reviewer 3:

The reviewer observed that future work is well-defined. The reviewer added that the team plans to perform electrical simulations to evaluate the effect of the dielectric fluid on electrical performance and perform power cycling on the ceramic-free module to evaluate for reliability. The reviewer recommended that experimental results be compared with analytical and simulation results in the future. The reviewer noted that a comparison with today's technology, where the ceramic layer is used, is done.

Reviewer 4:

The reviewer declared that the specific study point for the electrical simulations relative to the cooling fluid dielectric properties was not clear. The reviewer asked what will be studied and how, especially numerically. The reviewer added that the statement, "collaborate with Georgia Tech to develop the advanced cooling technologies," is generic and asked what exactly will be done.

Reviewer 5:

The reviewer mentioned that electric and reliability evaluation is essential.

Reviewer 6:

The reviewer thought it is an appropriate plan given the level of funding.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that the project addresses an alternative cooling strategy that would support an increase in power density for inverters.

Reviewer 2:

The reviewer noted that this project is relevant to VTO sub-program in electrification area and aligns with the keystone project objective for 100 kW/L power-dense inverter.

Reviewer 3:

The reviewer stated that DOE year 2025 targets 100 kW/L for power electronics, and that the project tries to achieve this target by contributing to the advanced cooling of power electronics using dielectric fluids and novel packaging techniques for semiconductor power switches.

Reviewer 4:

The reviewer declared that this project is highly relevant to the cooling of high heat flux semiconductor devices for future power conversion systems.

Reviewer 5:

The reviewer said it is fully relevant.

Reviewer 6:

The reviewer remarked that how to thermally manage high density power electronics is a key area for the program.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer observed that the work appears to be scaled appropriately to the resources available.

Reviewer 2:

The reviewer noted that the project has necessary resources and research funds.

Reviewer 3:

The reviewer declared that the resources are adequate.

Reviewer 4:

The reviewer thought that the resources appear to be sufficient.

Reviewer 5:

The reviewer affirmed that the next phase will reflect the effect of needed strong collaboration between thermal and electrical teams.

Reviewer 6:

The reviewer remarked that based on the level of funding available, the project has adequate resources, but things really should be happening at a faster pace if they are going to help industry compete.

Presentation Number: ELT215
Presentation Title: Develop fine-grain Rare Earth permanent magnet with high coercivity at high temperature AND cost-effective manufacturing process for high performance soft magnetic materials in thin sheet form
Principal Investigator: Iver Anderson (Ames Laboratory)

Presenter

Iver Anderson, Ames Laboratory

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.

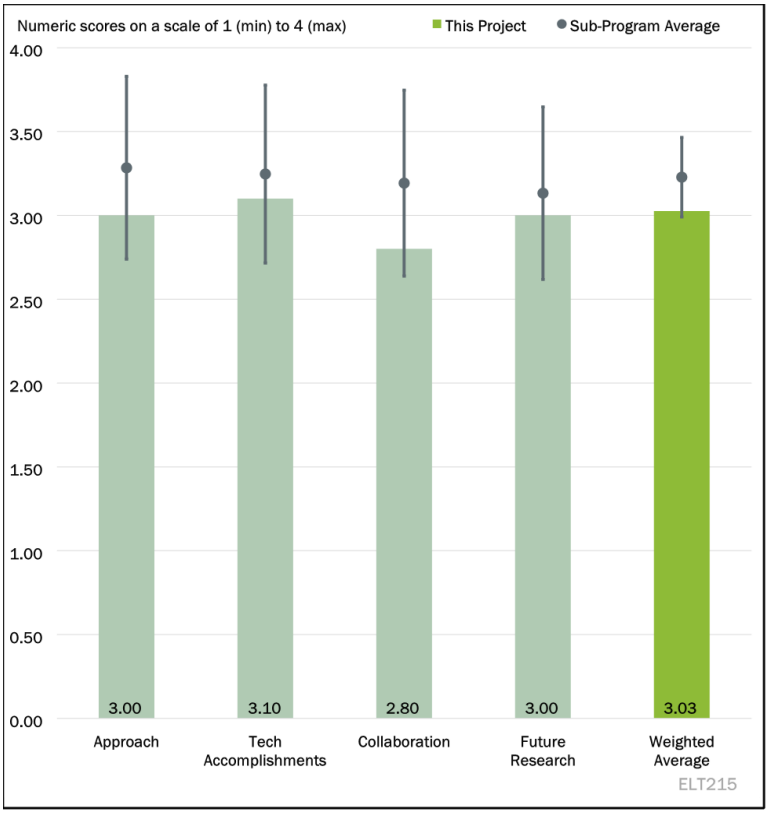

Figure 2-7 - Presentation Number: ELT215 Presentation Title: Develop fine-grain Rare Earth permanent magnet with high coercivity at high temperature AND cost-effective manufacturing process for high performance soft magnetic materials in thin sheet form Principal Investigator: Iver Anderson (Ames Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that the approach to perform the work is rational and shows a progression from early concepts to improved processing strategies and material chemistries. The reviewer said that sufficient time is allocated for iterative improvements considering new learnings and outcomes of the project work activities.

Reviewer 2:

The reviewer mentioned that the project is about developing better and cheaper magnets without using heavy rare earth elements. The reviewer explained that the project addresses the technical barriers of PMs being expensive and heavy rare earth (HRE) elements being scarce and their price volatility. The reviewer added that it also captures that non-rare earth PM electric motor has low power density, so a better solution is needed. The reviewer concluded that the project aims to achieve advanced processing to achieve high-energy PMs without scarce/costly HRE to achieve high-power density motors.

Reviewer 3:

The reviewer noted that this project is now in year five of a 6-year program; yet no data was shared regarding the progress towards the two specific goals of the project: drive motor power density and cost. The reviewer urged more focus be placed on these goals during the 2024 AMR.

Reviewer 4:

The reviewer declared that the project correctly identifies the technical barriers for permanent magnet and soft magnetic materials for advanced electric machines. The reviewer said that the plan to address these barriers could be improved if issues pertaining to production at full-scale could be included in the experimental plan. The reviewer asked that, for example, for passivation of permanent magnets, what degree of oxidation is acceptable in full-scale magnet manufacturing. The reviewer also asked what level of oxygen and dew point control are used in NdFeB magnet manufacturing are used today, and how much does the nitrogen trifluoride (NF_3) passivation method relax those requirements. The reviewer inquired that for the 6.5% silicon steel, what is the thickness and width, and annual production tonnage of 3% silicon steel produced today, and how close to this production capacity can melt-spun 6.5% Si steel achieve.

Reviewer 5:

The reviewer said it is not clear if successful how these materials will compare in terms of properties and cost to some of the commercially available materials especially permanent magnets that do not include heavy rare-earth materials.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer remarked that project progress has been significant and according to the project plan. The reviewer noted no major deficiencies, and several technical challenges identified, like oxidation of powders in permanent magnets and castability of soft magnetic alloys, have been overcome to some extent through modifications to material chemistries and/or processing techniques. The reviewer stated that work still remains to understand how to manufacture required powder feedstock for the permanent magnet activities and further optimization of castability and thickness is required for the soft magnetic alloys.

Reviewer 2:

The reviewer said that the project accomplished its primary goals, including designing and building a passivation powder collection chamber, carrying out trial runs and establishing a relationship among passivation parameters, powder oxidation, and powder magnetization, and investigating the effect of the passivation layer on sintering density and building magnet properties. The reviewer commented that the results have been well explained, figures were shown, and successes and challenges are well explained.

Reviewer 3:

The reviewer observed that there is a good approach of using three unique methods of milling the magnetic materials. The reviewer would have liked to hear more about the next generation of soft materials on Slide 20, but the presenter ran out of time. The reviewer offered that the project assumptions should be clearer, perhaps on a separate slide.

Reviewer 4:

The reviewer mentioned that the technical accomplishments have been good relative to the project plan. The reviewer remarked that the inability to attempt multi-jet jet milling due to equipment availability appears to have required a pivot to laboratory-scale milling methods which may not adequately approximate the jet milling process. The reviewer noted that the melt spun 6.5% silicon steel has completed proof-of-concept experiments, but the applicability to electric machine technology remains undemonstrated. The reviewer added that it is not clear if the reduction in watt loss at 1 kHz on Slide 18 is due to the higher resistivity of the melt spun 6.5% silicon steel or the thinner thickness of the meld spun material.

Reviewer 5:

The reviewer highlighted that it is important to include some information showing the expected motor performance using current or projected material properties.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer stated that the work appears to be largely independent of other project activities, with limited input and guidance on necessary material properties.

Reviewer 2:

The reviewer noted that the project collaborates excellently with national laboratories (ORNL, NREL, and Sandia) and other universities. The reviewer commented that there is a productive relationship, and collaboration results are clearly shown.

Reviewer 3:

The reviewer did not see any citations for Sandia or the university partners, but there was a good collaboration with ORNL and NREL.

Reviewer 4:

The reviewer remarked that collaboration with industry could be substantially improved. The reviewer explained that there are now several domestic companies attempting to establish NdFeB manufacturing facilities, like MP Materials, Noveon, GKN Hoeganaes, and Advanced Magnet Laboratory, and could provide input on the NF_3 passivation method. The reviewer added that domestic steel manufacturers like Cleveland-Cliffs formerly AK Steel, ATI Specialty Materials, and Carpenter Technology Corporation, could provide input on the scalability of the melt spun 6.5% silicon steel material.

Reviewer 5:

The reviewer said that there seems to be good collaboration among the national laboratories.

Question 4: Please comment on the 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 the project has defined future pathways that are rational and logical. The reviewer remarked that the scalability of the manufacturing pathways chosen should be a primary emphasis to enable technology transfer.

Reviewer 2:

The reviewer commented that future research direction is well-provided by mentioning the development of novel gas atomization-based powder production methods sufficiently to replace the conventional energy and labor-intensive strip casting method. The reviewer noted that there are undoubtedly improvement opportunities in this fundamental research in the future.

Reviewer 3:

The reviewer observed that future research ideas are very good; however, the project team needs to specifically address the targets and challenges identified early in the presentation.

Reviewer 4:

The reviewer stated that proposed future research plans adequately identify the remaining technical issues that must be addressed. The reviewer offered that additional interaction with industrial stakeholders will maximize the chance that the technology will be commercially adopted.

Reviewer 5:

The reviewer said that the plan is reasonable if previous comments are addressed.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer mentioned that new materials are a critical enabler for next generation electrical machines.

Reviewer 2:

The reviewer stated that the project meets the DOE VTO objectives by eliminating heavy rare element use and achieving ultra-fine grain magnet technology. The reviewer suggested that the results are promising in terms of achieving the goals of this fundamental research. The reviewer remarked that the collaboration with other national laboratories and universities is noteworthy.

Reviewer 3:

The reviewer noted that this project fits very well with VTO objectives.

Reviewer 4:

The reviewer commented that the project is of prime relevance to the Electrification subprogram and addresses a critical need for the development of advanced and improved magnetic materials.

Reviewer 5:

The reviewer remarked that the targeted materials would improve motor performance, but this needs to be quantified.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked that the project resources seem sufficient for the current scale of work pursued, but to enable future manufacturing scalability additional resources will be required.

Reviewer 2:

The reviewer noted that resources are adequate.

Reviewer 3:

The reviewer was sure that Covid impacted this project, just as it did most of the other projects. The reviewer expressed that it seems that there is a lot of work still needed to complete the project and measure the results against the goals and challenges. The reviewer suggested that perhaps a 1-year extension would be appropriate.

Reviewer 4:

The reviewer stated that further resources should be applied to this project to accelerate the development and commercialization of improved and advanced permanent magnets and soft magnetic materials. The reviewer suggested that the resources should be directed at the gaps preventing demonstration of pilot scale manufacturing of the technology.

Reviewer 5:

The reviewer declared that resources are sufficient based on the scope.

Presentation Number: ELT216
Presentation Title: Isotropic, Bottom-Up Soft Magnetic Composites for Rotating Machines
Principal Investigator: Todd Monson (Sandia National Laboratories)

Presenter

Todd Monson, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers 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.

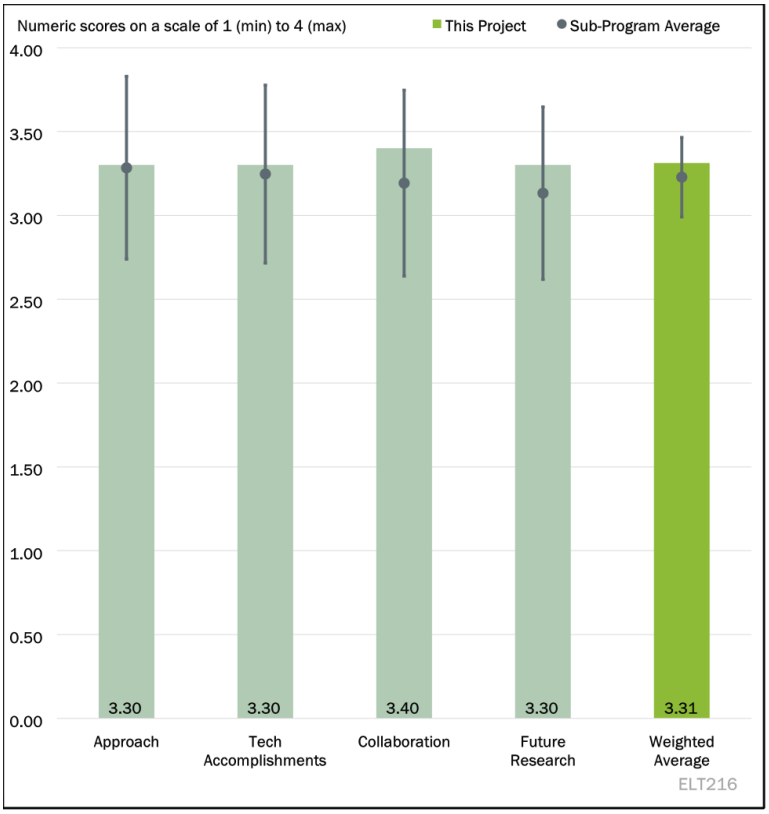

Figure 2-8 - Presentation Number: ELT216 Presentation Title: Isotropic, Bottom-Up Soft Magnetic Composites for Rotating Machines Principal Investigator: Todd Monson (Sandia National Laboratories)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that the project has a clear aim of developing new soft magnetic materials for electric motor applications through a bottom-up manufacturing process involving high flux density iron nitride materials. The reviewer noted that a systematic approach to the work plan has been pursued with continued progress demonstrated.

Reviewer 2:

The reviewer remarked that the project aims to develop soft magnetic materials which have high performance magnetically. The reviewer said that if successful, alternative motors to permanent magnet motors can be achieved. The reviewer added that the project aims to eliminate cost barriers of rare earth elements and higher temperature capability. The reviewer observed that the work is consistent with replacing permanent magnets with soft magnet materials mentioned in the Electrical and Electronics Technical Team Roadmap as an alternative R&D pathway for achieving 2025 targets.

Reviewer 3:

The reviewer said that the approach and timeline are both appropriate for this project.

Reviewer 4:

The reviewer mentioned that the project addresses the technical barriers relevant to the engineering of a soft magnetic composite. The reviewer added that the project would be improved if the achieved and targeted

properties were benchmarked against commercially available soft magnetic composites, like AncorLam and Somalloy.

Reviewer 5:

The reviewer suggested that a more detailed comparison of how the new material compare to commercially available materials should be provided.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated that the team has made substantial progress when benchmarked with prior reporting, including increases in magnetic volume fraction within composites, mechanical testing, and additional sample manufacturing to various geometries.

Reviewer 2:

The reviewer remarked that the project fabricated a 50% scale version of the dual rotor homopolar AC machine (DHAM) short stator assembly using 55% Fe_4N and developed protocols for fabricating, curing, and polishing Fe_4N/epoxy motor components. The reviewer added that tests were conducted to test the mechanical and electrical aspects of Fe_4N/epoxy composite properties. The reviewer commented that toroids for inductor design were built with the new material. The reviewer stated that it is good to see that the soft magnetic material developed is adapted to an actual machine design, and that this project demonstrates the material development concept to non-rare earth motor design.

Reviewer 3:

The reviewer noted that the technical progress is good; however, there is still a lot of work to get done with only 1 year remaining in the timeline.

Reviewer 4:

The reviewer observed that the project has systematically completed the significant structure, processing, and property milestones needed for a materials engineering effort.

Reviewer 5:

The reviewer mentioned that the detailed comparison of proposed motor with the novel material relative to a well-established baseline should be provided.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer noted that the team is effectively collaborating with numerous partners and is clearly identifying their contributions to the on-going work.

Reviewer 2:

The reviewer stated that the project collaborates with NREL, Ames National Laboratory, ORNL, Purdue University, and Illinois Institute of Technology (IIT). The reviewer observed that the engagement with Purdue University is focused on a motor design utilizing a DHAM that uses the proposed material. The reviewer said that this kind of engagement is appreciated to take the material science from the laboratory environment for an actual implementation on an end unit, in this case, a motor.

Reviewer 3:

The reviewer observed the excellent collaboration across the entire team and was sure that IIT will get more involved when dynamometer testing begins. The reviewer stated that the reference to ELT248 was also very good.

Reviewer 4:

The reviewer commented that the level of collaboration has been good and that it seems that the majority of the experimental work has been performed at NREL. The reviewer stated that the results of the DHAM motor prototype with the fabricated components will be critical to assessing the feasibility of the technology.

Reviewer 5:

The reviewer noted that there seems to be good collaboration among participating organizations.

Question 4: Please comment on the 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 work is rational and will continue to yield progress towards the overall stated objectives. The reviewer declared that some questions remain which should be addressed to assist in further justifying the work plans and clarifying the overall project objectives:

Current saturation flux densities are approximately 1.2 T, how does this compare to state of art soft magnetic composites using more traditional metallic alloys? What advantages does the iron nitride approach yield at this flux density?

Permeabilities of more than 100 are targeted, how does such a low permeability impact motor performance in terms of efficiency and torque? What would be the ideal target if it could be selected?

Temperature stability is discussed for the epoxy but not the iron nitride material. Given that the stability of the nitride phase may be questioned by some potential end-users, it would be wise to clearly represent as compared to other thermal limitations associated with the composite materials.

Reviewer 2:

The reviewer observed that the proposed future includes fabricating the DHAM rotor and stator using soft magnetic components and continuing process and performance improvements of Fe_4N/epoxy composites. The reviewer added that epoxy is needed for high-speed operations of the motor, and there is a need to develop a sleeve. The reviewer said that it would be nice to see this work completed in the next budget period.

Reviewer 3:

The reviewer remarked that the future research has been clearly identified and is well aligned with the goals of the project.

Reviewer 4:

The reviewer noted that the future research plans include fabrication and testing of a DHAM prototype and further improvements in the material properties.

Reviewer 5:

The reviewer stated that previous comments need to be addressed.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer mentioned that the project is clearly aligned.

Reviewer 2:

The reviewer remarked that the project aims to develop soft magnetic material for motor design. The reviewer added that the proposed material can be used on motor topologies that do not have rare earth permanent magnets. The reviewer concluded that since rare earth materials are critical materials, this project aligns well with VTO subprogram objectives.

Reviewer 3:

The reviewer commented that this project fits very well into the objectives of VTO and that it seems that much more research in this particular area is justified.

Reviewer 4:

The reviewer affirmed that the project supports the Electrification subprogram objectives by demonstrating the performance of an advanced soft magnetic composite material.

Reviewer 5:

The reviewer noted that the project is relevant to the goal of eliminating rare-earth material but improvement in performance is not very clear.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the current resources are adequate; however, if it is desired to explore manufacturing scalability, resource requirements will increase substantially.

Reviewer 2:

The reviewer remarked that the project has adequate resources to carry out the planned task.

Reviewer 3:

The reviewer noted that the project has huge potential but would need significantly more funding to achieve all of the potential milestones applicable to this technology.

Reviewer 4:

The reviewer said that the resources are sufficient.

Reviewer 5:

The reviewer observed that the resources sufficient based on scope.

Presentation Number: ELT219
Presentation Title: Power Electronics Materials and Bonded Interfaces-Reliability and Lifetime
Principal Investigator: Paul Paret (National Renewable Energy Laboratory)

Presenter

Paul Paret, National Renewable Energy Laboratory

Reviewer Sample Size

A total of 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.

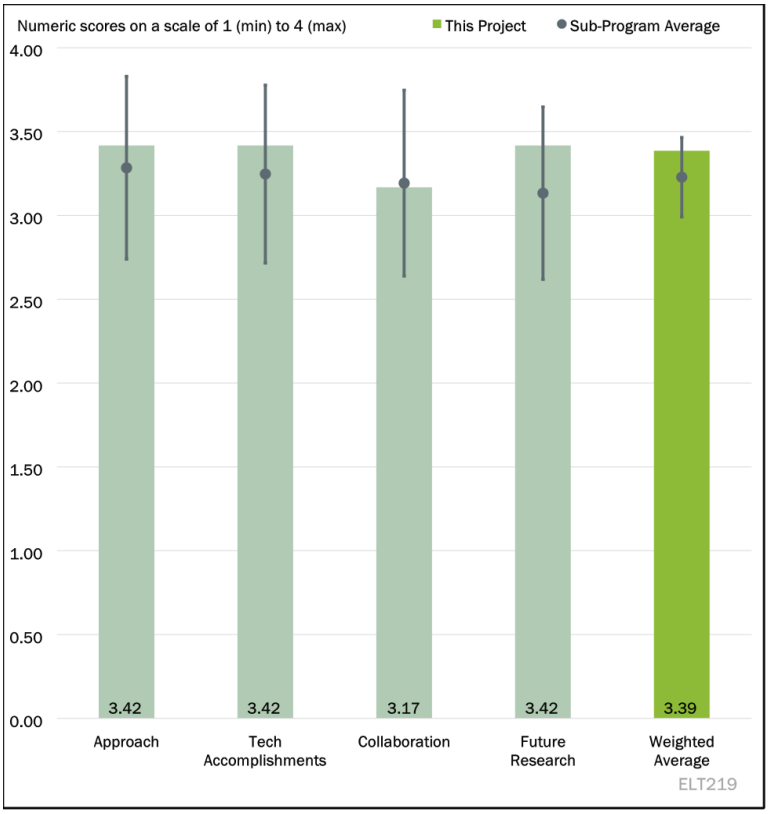

Figure 2-9 - Presentation Number: ELT219 Presentation Title: Power Electronics Materials and Bonded Interfaces-Reliability and Lifetime Principal Investigator: Paul Paret (National Renewable Energy Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that the team is using an appropriate mix of destructive and non-destructive testing and is comparing the test results to prediction models.

Reviewer 2:

The reviewer noted that the reliability of bonded interfaces in power modules is critical to the reliability of power electronics converters. The reviewer added that the team has designed an excellent approach to study the issue through a combination of sample preparation, testing, and finite-element analysis.

Reviewer 3:

The reviewer remarked that the scope of work involves systematic variation in processing of bonded interfaces, a critical component of device reliability. The reviewer added that variations are followed by imaging and thermal and mechanical testing to confirm adhesion and quality of bonds. The reviewer suggested that additional consideration should be made for using electrical and thermal performance metrics to assess bond quality and performance in addition to mechanical adhesion.

Reviewer 4:

The reviewer noted that the project looks to evaluate polymeric and copper bonding approaches in addition to machine learning techniques for life prediction to understand capabilities of the technologies. The reviewer

mentioned that the approach seems good but that the grid and stripe patterning for the Cu bond layer is a little strange and might actually induce failure earlier than expected due to more stress concentrations at the edges of the grids or stripes and localization of heat during actual power device operation. The reviewer recommended to study these possible effects if the researchers decide to proceed with the approach.

Reviewer 5:

The reviewer noted that the reliability evaluation of bonded interfaces and the lifetime prediction model based on time-series forecasting are critical elements. The reviewer expressed that the missing element is that of the joint fabrication process. The reviewer explained that the manufacturing process is just as big a factor as the material makeup of the joint. The reviewer added that without control or at least full understanding of what is being fabricated, it is difficult to know what the experimental research results mean.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated that the team has fabricated and tested multiple bonding materials and methods. The reviewer added that the sintered copper results are a little bit difficult to interpret. The reviewer remarked that the team has compared time-series forecasting to machine learning and demonstrated the superiority of statistical models, and that this is encouraging and illustrates the importance of evaluating a range of approaches. The reviewer commented that on Slide 8, there is a graph that is totally unreadable for someone who is colorblind because the color contrast is not sufficient. The reviewer explained that this is a situation where marker types or line styles would be extremely beneficial so as not to rely on color alone to communicate; by comparison, Slides 7, 11, and 12 are excellent from that perspective.

Reviewer 2:

The reviewer observed that the team has made significant progress in evaluating the reliability of polymer-bonded interfaces by sample synthesis and testing. It was not clear to the reviewer why the two polymers were selected for study. The reviewer found that reliability evaluation of sintered-copper interface was interesting and looks forward to seeing more results in the following year.

Reviewer 3:

The reviewer said that the project seems to be tracking according to the initial plan.

Reviewer 4:

The reviewer noted that good progress is made across all thrusts.

Reviewer 5:

The reviewer stated that given the level of funding, progress was reasonable.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer stated that while the team overall seems appropriate, the relative contributions of Georgia Tech and the three national laboratories is unclear.

Reviewer 2:

The reviewer noted the excellent collaboration with Institute of Innovative Mobility (IIMo) leading to the sintered copper samples.

Reviewer 3:

The reviewer remarked that the sample exchanges between project partners have been effective, but that it is not clear if there is strong interaction with other national laboratory partners given the work scope.

Reviewer 4:

The reviewer commented that it was not very clear beyond the simple one-line sentences in the presentation what the contributions of the various partners is.

Reviewer 5:

The reviewer did not see much detail of the level of collaboration and stated that there is a need to better understand exactly what is being done by each of the participants.

Question 4: Please comment on the 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 team has identified the issues with their work up to this point and identified the appropriate next steps to explore reliability of all three bonding technologies.

Reviewer 2:

The reviewer noted that the proposed future activities are excellent and in line with the program objectives and approach.

Reviewer 3:

The reviewer commented that, as noted above, the project should work towards electrical and thermal performance figures of merit as the project matures. The reviewer added that given the early status, it is expected that the project will be focused on earlier screening and assessment methods.

Reviewer 4:

The reviewer suggested that it would be nice to see the development of constitutive models for enhanced numerical study of these newer materials being proposed, but it was not.

Reviewer 5:

The reviewer noted that based on the budget, the proposed future research is reasonable.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that bond reliability is essential in all power electronics packages.

Reviewer 2:

The reviewer said that understanding the reliability of bonded interfaces, which determines the reliability of power modules and power converters is critical for achieving the VTO Electrification's targets for electric traction drives.

Reviewer 3:

The reviewer commented that bond reliability can be a critical factor in dictating the overall lifetime, and that the project is highly relevant to overall goals.

Reviewer 4:

The reviewer noted that the project furthers the advancement of electrified vehicle systems with WBG devices.

Reviewer 5:

The reviewer noted that this area will be a key factor in increased power density and lower cost.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer declared that the work appears to be properly scaled to the resources available.

Reviewer 2:

The reviewer noted that the project has adequate resources.

Reviewer 3:

The reviewer observed that for the current scope of work, the resources seem reasonably aligned. The reviewer suggested that future years should reassess based on progress and proposed future work efforts.

Reviewer 4:

The reviewer stated that resources seem sufficient, but they could be enhanced if the researchers can better develop constitutive models.

Reviewer 5:

The reviewer said that this project should be more comprehensive. The reviewer remarked that there should be a team working on the manufacturing processes with the materials selection, then a team doing the evaluation. The reviewer noted that right now there is just a team working on the evaluation of the fabricated joints.

Presentation Number: ELT221
Presentation Title: Integrated Electric Drive System
Principal Investigator: Shajjad Chowdhury (Oak Ridge National Laboratory)

Presenter

Shajjad Chowdhury, Oak Ridge National Laboratory

Reviewer Sample Size

A total of 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.

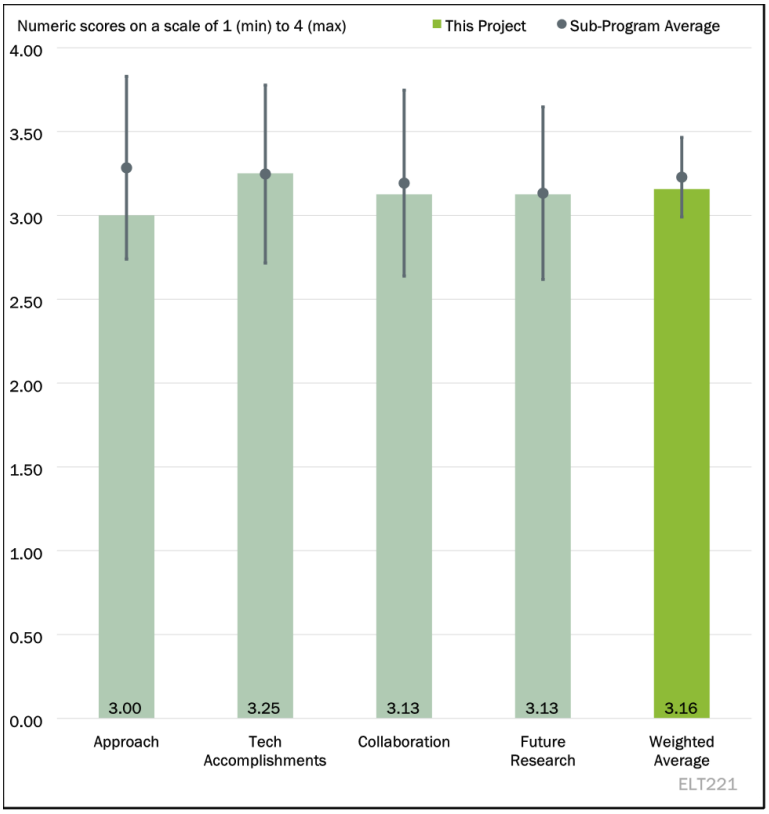

Figure 2-10 - Presentation Number: ELT221 Presentation Title: Integrated Electric Drive System Principal Investigator: Shajjad Chowdhury (Oak Ridge National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that the technical barriers are mentioned and addressed appropriately.

Reviewer 2:

The reviewer asked if the primary goal is to build a high-power density inverter and integrate it with the electric machine without any efficiency targets to be met, or if the efficiency targets will be specified in the design of the individual components. The reviewer explained that without a minimum efficiency target, it may be possible to build an integrated high-power density electric drive machine (EDM) using a cooling strategy which would otherwise be unacceptable. The reviewer added that if it is not the case, it would still be good to clarify the efficiency targets. The reviewer noted that there appears to be no stated cost target either. The reviewer did not have a good idea of the costs involved, but asked if moving to a modified DBC substrate or DBC with TPG would adversely impact the cost.

Reviewer 3:

The reviewer remarked that all the relevant thermal and electromagnetic barriers seem to be adequately addressed, and that mechanical stresses due to coefficient of thermal expansion will be addressed in the future.

Reviewer 4:

The reviewer observed that most of the details are focused on the inverter design, and that there were not enough details about the integration of the inverter and the motor as well as the overall thermal management system.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer commented that the project appears to be on track and all the promised deliverables met.

Reviewer 2:

The reviewer remarked that the completed testing is in line with the milestones and go/no-go decision gates. The reviewer added that the test results also support the going in postulates and provide the cooling performance improvement that is needed to achieve the high-power density.

Reviewer 3:

The reviewer stated that the team has made good progress towards meeting the technical project goals.

Reviewer 4:

The reviewer observed that there was good progress on designing the inverter. The reviewer added that the choice of an outer rotor motor design might not be optimum and actually limiting, as outer rotor motors are known to have several mechanical challenges. The reviewer stated that more specific details about the system integration should be provided, and that more thermal and mechanical analysis of the overall system should be provided.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer declared that clear leadership is evident, which drives results. The reviewer encouraged more industry involvement so as to insure relevancy. Overall, the reviewer was glad to see the ability to leverage strengths of the individual national laboratories.

Reviewer 2:

The reviewer noted very good collaboration with the other national laboratories; however, it may be beneficial to have commercial manufacturers on power inverters involved to better assess impact of chosen design on piece cost in volume production, or any other issues such as reliability, durability, and variability that may arise.

Reviewer 3:

The reviewer commented that the results from collaboration with NREL, Sandia, and Ames have not been presented yet.

Reviewer 4:

The reviewer remarked that there seems to be collaboration among several organizations, but more specific details need to be provided.

Question 4: Please comment on the 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 is on track, clearly defined and documented, and the reviewer is looking forward to next year.

Reviewer 2:

The reviewer said that the future plan looks good, but as mentioned in an earlier section, it would be good to have some clear system level efficiency and cost targets specified for this project.

Reviewer 3:

The reviewer noted that the proposed research adequately addressed the main challenges and is likely to achieve its targets.

Reviewer 4:

The reviewer observed that, in general, the direction is good but some of the areas that need more details should be addressed.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that this project is one of electrification's top current projects.

Reviewer 2:

It was not clear to the reviewer how feasible it will be to use the EDM configuration that is being developed in this project in serial production, but nevertheless, the reviewer expressed that the experience gained and techniques developed here could be deployed in other configurations in the march towards developing a high-power density and cost effective electric drive unit.

Reviewer 3:

The reviewer noted that the project is directly relevant towards meeting the Electrification subprogram's 2025 power density target of 33 kW/L.

Reviewer 4:

The reviewer commented that the end goal of having tightly integrated systems with improved thermal performance is relevant.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the cost appears to be insufficient and suggested increasing it.

Reviewer 2:

The reviewer thought the resources are sufficient.

Reviewer 3:

The reviewer declared that the project appears to have sufficient resources to achieve the stated milestones.

Reviewer 4:

The reviewer believed that the resources are sufficient based on the proposed scope.

Presentation Number: ELT223
Presentation Title: Component Testing, Co-Optimization, and Trade-Space Evaluation
Principal Investigator: Jason Neely (Sandia National Laboratories)

Presenter

Jason Neely, Sandia National Laboratories

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers 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.

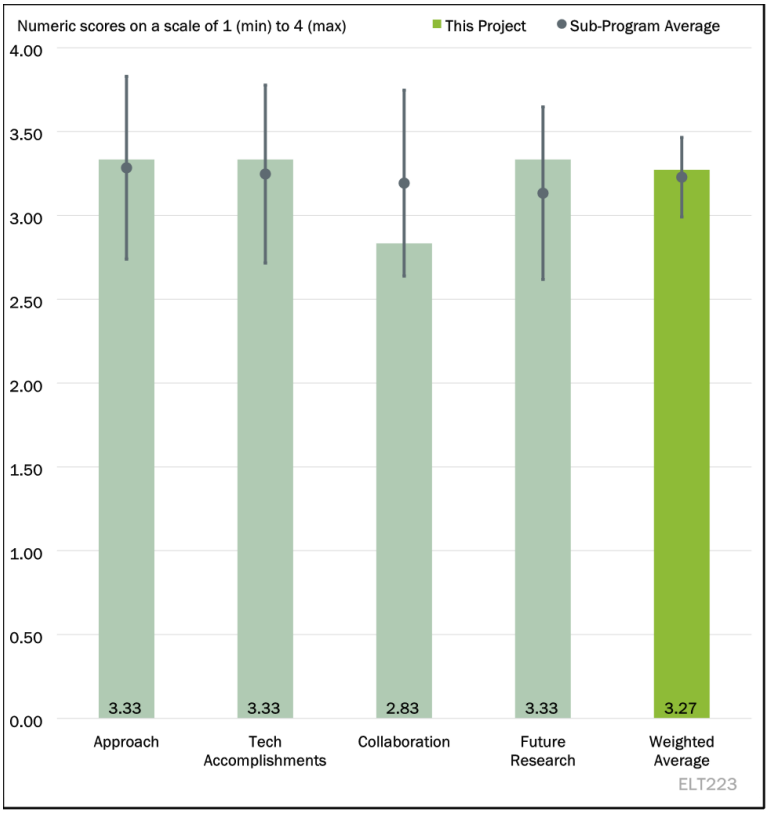

Figure 2-11 - Presentation Number: ELT223 Presentation Title: Component Testing, Co-Optimization, and Trade-Space Evaluation Principal Investigator: Jason Neely (Sandia National Laboratories)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer noted the excellent use of the modeling tools, and that sufficient detail was included to clearly understand the approach.

Reviewer 2:

The reviewer commented that in general, vehicles sold in the United States are going to require higher power than 100 kW, because SUVs and trucks make up a large percentage of vehicles sold. The reviewer added that 100 kW peak power rating will correspond to perhaps about 50 kW continuous power. The reviewer stated that if a vehicle is loaded up to its gross vehicle weight rating, or it is towing a payload, and driving on a freeway at more than 70 mph for extended periods of time, the continuous power rating becomes critical. The reviewer concluded that a 100 kW peak power machine would be woefully inadequate and using the Supplemental Federal Test Procedure (SFTP or EPA US06) as a mission profile to evaluate operational life may not be sufficient. The reviewer did not know about Tesla, but legacy OEMs generally design their vehicles to meet the needs of a 95% customer. The reviewer said that this generally means requiring the vehicle to be able to pass more extreme test conditions, such as driving up the Davis Dam grade at 65 mph, while towing, at ambient temperatures of 1100°F. The reviewer suggested seeing SAE J-2807 for towing requirements. The reviewer mentioned that certification cycles, like Federal Test Procedure (FTP) 5 cycle, are required to be used by OEMs to calculate vehicle range; however, it is also worthwhile to include efficiency calculations using more “real world” type of driving. The reviewer noted that a lot of work in this area has been done at NREL

and has been presented in past AMRs. The reviewer mentioned that verifying the efficiency gains using real world driving cycles ensures that the efficiency gains seen in the calculations are actually seen by the consumer, and the former goal of petroleum displacement is actually achieved.

Reviewer 3:

The reviewer stated that issues that go along with implementing surround cooling, or distributed bus filtering have not been identified, and that the evaluation needs to measure these other potential issues for the technology to be usable.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that the technical progress has been in line with the original objectives and that the approach is very disciplined. The reviewer remarked that it was very interesting that increasing the flow rate to 600 mm^3/sec had little impact to the results on Slide 5.

Reviewer 2:

It appeared to the reviewer that the project has taken direction which have not led to fruitful results by utilizing a distributed bus filter, but it is still valuable information that is gained by trying these approaches and should benefit future projects. The reviewer explained that one issue with the distributed filter approach is the reliance on higher switching frequency (100 kHz), which appears to require GaN components. The reviewer added that most manufacturers are not considering GaN semiconductors as an option yet because of limited reliability and that this would be in direct contrast to the stated goal of 300,000 miles.

Reviewer 3:

The reviewer stated that based on the budget, the progress is reasonable, but the reviewer saw gaps in this project. The reviewer explained that there needs to be a more holistic approach that encompasses all issues around the technologies being pursued.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer stated that it was not clear from the presentation which parts of this project were performed by each of the team members and suggested that more detail should be included in the final report.

Reviewer 2:

The reviewer commented that while collaboration with other national laboratories and universities has been excellent, the project could definitely benefit from some involvement from the industry as well. The reviewer noted that any of the points made in the above response are from an industry perspective.

Reviewer 3:

It was not clear to the reviewer to what extent the activity between collaboration participants exists other than the statements on Slide 16.

Question 4: Please comment on the 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 in line with the original project objectives.

Reviewer 2:

The reviewer remarked that the proposed future work is very worthwhile. Regarding the multi-objective optimization approach, and after over thirty years in the industry, the reviewer held the very contrary opinion that in many cases multi-objective optimization does not necessarily yield a solution that is implementable. The reviewer explained that it is a great approach when developing a one-off prototype which has very specific requirements. The reviewer added that in practice though, the same components of power electronics, electric machines, etc. will have to be used in multiple vehicle programs in order to keep the cost within reason. The reviewer concluded that the requirements on the components span a wide range in terms of power, torque, packaging, mission profiles, etc., but they all have to be met by the same set of components. The reviewer said that this, in most cases implies that, components that end up being used are not usually those that are arrived at as the outcome of a multi-objective optimization.

Reviewer 3:

The reviewer stated that the proposed work for Fiscal Year 2024 seems to be reasonable given the current project status.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer remarked that the relevance and objectives identified are aligned with VTO objectives.

Reviewer 2:

The reviewer said that the project is definitely relevant, and that any progress made that will help improve vehicle range, cost, performance, and would lead to adoption of these ideas by the industry would be beneficial.

Reviewer 3:

The reviewer stated that this is an important area of work, but believed it needs to be more in depth in order for it to be really valuable to industry.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

It appeared to the reviewer that the resources have been distributed over the 5-year timeframe effectively.

Reviewer 2:

The reviewer said they are sufficient.

Reviewer 3:

The reviewer stated that there needs to be a more in-depth project defined to answer the questions the current project is trying to answer, and that this will take more resources to be done properly.

Presentation Number: ELT236
Presentation Title: Direct-Current Conversion Equipment Connected to the Medium-Voltage Grid for Extreme Fast Charging Utilizing Modular and Interoperable Architecture
Principal Investigator: Watson Collins (Electric Power Research Institute)

Presenter

Watson Collins, Electric Power Research Institute

Reviewer Sample Size

A total of 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.

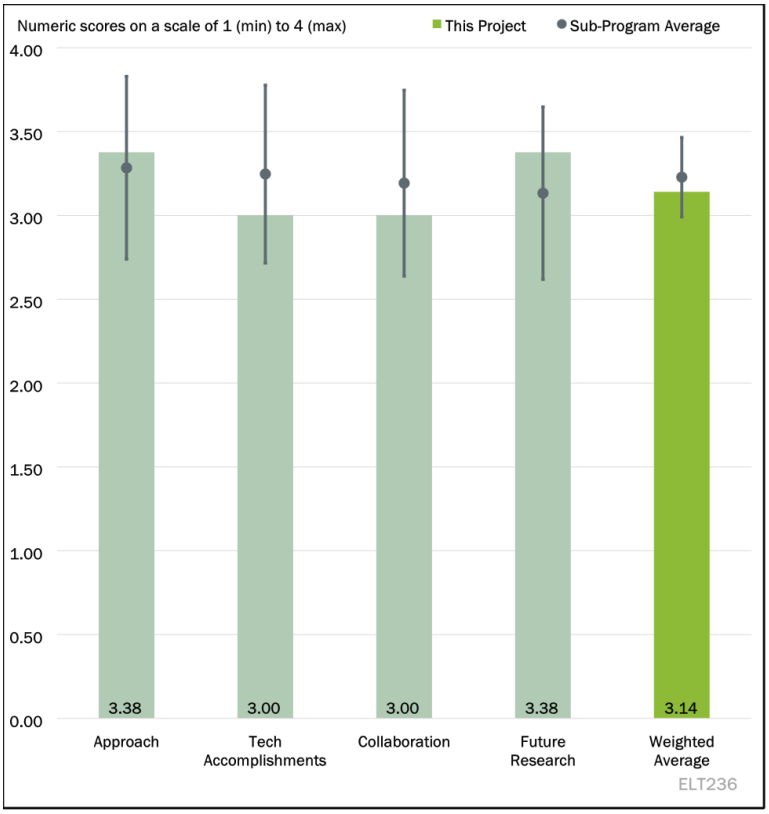

Figure 2-12 - Presentation Number: ELT236 Presentation Title: Direct-Current Conversion Equipment Connected to the Medium-Voltage Grid for Extreme Fast Charging Utilizing Modular and Interoperable Architecture Principal Investigator: Watson Collins (Electric Power Research Institute)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that the project appropriately segments the work into five core components: utility interface; medium voltage converter (solid-state transformer); DC load center; direct current fast chargers (DCFCs); and testing with extreme fast charging capable vehicles. The reviewer added that all segments are pushing the envelope of technology as commercial components for each are still in development or just coming to the market.

Reviewer 2:

The reviewer mentioned that the technical barriers are being addressed and the project design is appropriate. The reviewer added that one possible shortcoming is that there is no mention of evaluating the reliability of the solid-state transformer.

Reviewer 3:

The reviewer noted that the project is on track.

Reviewer 4:

The reviewer commented that one technical barrier that this project seeks to address is integrating distributed energy resources (storage, solar, wind, etc.) to enable management of DC connected EV charging. The

reviewer added that as the project proceeds, the degree to which the equipment solves this integration can be explored further.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer remarked that there was good progress on solid-state transformer with the design completed and prototype cells tested, request for quotes issued, and four vendors short-listed, and on the DC load center which was built and tested. The reviewer added that due to supply chain delays, the three 360 kW Tritium DC charging heads are delayed until 2024, but instead a 150 kW prototype has been delivered to NREL for testing with laboratory equipment.

Reviewer 2:

The reviewer commented that the progress is good considering that much of the original project schedule has been delayed by Covid and supply chain issues.

Reviewer 3:

The reviewer affirmed that there is a need to assure all test conditions are considered especially environmental and temperature variations.

Reviewer 4:

The reviewer stated that, as reported, the project did face challenges with the supply chain interruptions and changes in vendor participation. The reviewer noted that the project team awaits delivery of hardware components before they can be assembled in one location and tested at the NREL facility.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer commented that Electric Power Research Institute (EPRI) as the project lead is collaborating with Tritium as a DC charging heads supplier and NREL for comprehensive system testing. The reviewer added that Argonne National Laboratory was listed as a project partner, but their role was not mentioned in the presentation.

Reviewer 2:

The reviewer stated that the partner participation appears to be balanced and appropriate.

Reviewer 3:

The reviewer noted that this section was not adequately presented.

Reviewer 4:

The reviewer commented that, notwithstanding supply chain and vendor response or delays, the project team noted it is expecting to take delivery on hardware components, which can then be assembled and tested by NREL. The reviewer added that the team noted an increasing number of manufacturers and vendors are building prototypes of solid-state transformers, for example, so the options may be growing in the market. The reviewer concluded that the team seems to be bringing together the collaborators well.

Question 4: Please comment on the 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 due to the supply chain delays the three Tritium 360 kW DC charging heads are anticipated to arrive at NREL in 2024 for system testing. The reviewer added that the demonstration site selection is to be made by the end of budget period three, and that the team is currently considering a utility site in Pomona, California, which will be ready in 2023.

Reviewer 2:

The reviewer mentioned that future research appears outstanding because it addresses quantifying the reliability and resiliency of the DC infrastructure and proposes to perform additional integration of the DC microgrid with medium voltage converters. The reviewer added that the proposed failure mode analysis would also be useful for assessing this project's architecture.

Reviewer 3:

The reviewer suggested that the project team needs more test data and test conditions especially regarding impact and interface to grid.

Reviewer 4:

The reviewer remarked that the goal of enabling charging hardware that is interoperable and easily buildable and scalable (modular) supports the goals of VTO. The reviewer added that future work should show the interoperability, modularity, and scalability of the architecture. The reviewer commented that the project team proposes additional integration testing, megawatt charging implementation, dynamic response to unexpected system conditions, failure mode analysis, reliability and resiliency monitoring, and other future potential work. The reviewer suggested that it is important in considering future work, to seek input from eventual day-to-day users like the companies or fleets who own facilities where charging might occur or who run EVs and would utilize the integrated charging in their operations.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer mentioned that establishing a foundational system for DC connected EV charging that integrates with devices such as distributed energy resources, solar, wind, and energy storage contributes to addressing the VTO Electrification subprogram objectives to support electric transportation. The reviewer added that developing and testing extreme fast charging technologies while minimizing impacts to the grid directly supports the Grid and Charging Infrastructure program goals.

Reviewer 2:

The reviewer stated that this project is relevant to VTO Electrification subprogram objectives to develop enabling technologies for transportation electrification to include charging architectures that integrate with the electrical grid and distributed energy resources. The reviewer added that this project develops technologies that minimize the number of power conversion steps and uses a solid-state transformer and novel central DC load center.

Reviewer 3:

The reviewer offered that the project team needs to quantify economic values and impact.

Reviewer 4:

The reviewer remarked that this project is relevant to VTO subprogram objectives, particularly Electrification and grid integration activities. The reviewer added that the Batteries subprogram seeks to enable extreme fast charging for EV batteries, and this project also helps enable extreme fast charge (XFC) goals.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that $5 million total funding with $2.6 million DOE share seems appropriate for a grid integrated megawatt charging technology development project that is spanning nearly 7 years with the sought extension.

Reviewer 2:

The reviewer noted that the resources appear to be sufficient if the timeline is extended to allow the supply chain issues to be resolved; however, it is unclear whether the solid-state transformer (SST) manufacturing quotes will present a resource constraint issue.

Reviewer 3:

The reviewer remarked that the project is on track.

Reviewer 4:

The reviewer declared that the project team appears to be near completion of its work, though with an extension sought, but it was unclear whether it is a no-cost extension or if they are seeking additional funding.

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 Unviersity

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.

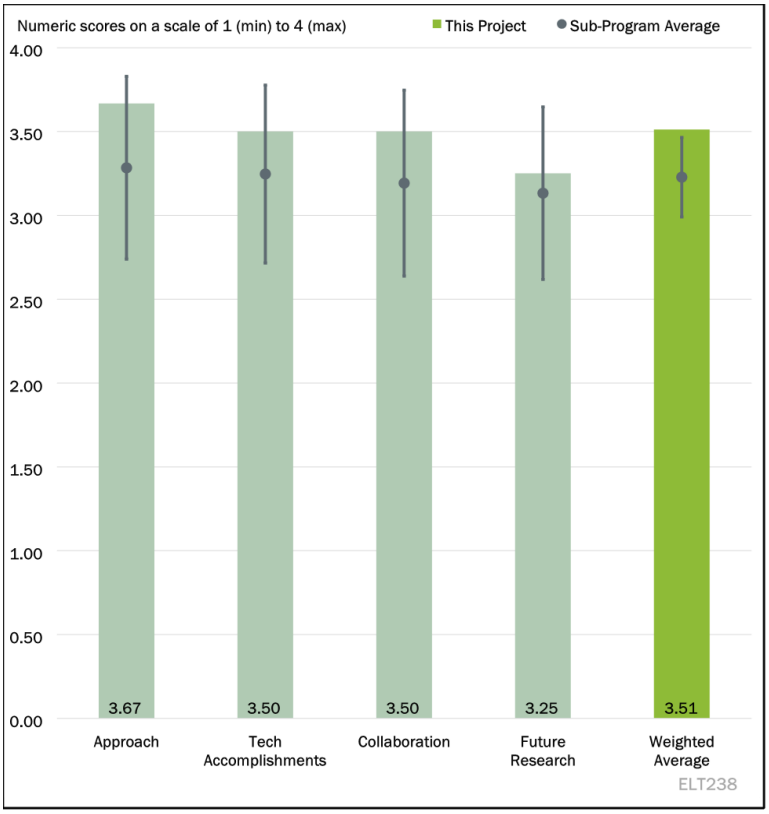

Figure 2-13 - Presentation Number: ELT238 Presentation Title: Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State Direct-Current Protection Principal Investigator: Srdjan Lukic (North Carolina State University)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer commented that great progress has been made on this project and with only field demonstration and testing remaining, it appears that the technical issues have been adequately addressed thus far. The reviewer added that the proof will now be in the installation and test.

Reviewer 2:

The reviewer remarked that this project has developed a prototype of extreme fast charging system rated at 1 megavolt-ampere (MVA). The reviewer added that since this is quite an expensive system, its uptime is crucial from a payback time standpoint. The reviewer stated that to ensure high uptime, the project team has developed a protection system capable of isolating the faulty portion of the power circuit within the extreme fast charging (XFC) system, followed by its testing with a single fault injected at a time. The reviewer concluded that overall, the approach was towards the realization of a reliable extreme fast charge (XFC) system.

Reviewer 3:

The reviewer noted that the approach follows three logical phases, and that the speaker's description provided details of each phase and the logical steps in each phase.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated that the plan was executed as architected with the only notable exception being the system assembly. The reviewer added that it has delayed the rest of the program, causing the system testing to be outside the originally proposed project plan, but that it will get covered in a no-cost extension. The reviewer noted that the delay is understandable as global supply chain issues impacted many industries. The reviewer said that significant work was performed on the solid-state transformers and solid-state breakers that can be a benefit to projects outside of this one. The reviewer remarked that these should be thoroughly tested both inside and outside the overall system. The reviewer realized that the installation and field test has yet to begin but suggested that the team be certain to have a thorough and comprehensive test plan to fully test single and double faults through combinations and permutations. The reviewer stated that even now, before installation, the fault detection and control logic can be tested on a low-voltage bench; there was no mention of it. The reviewer said that one of the key aspects of this project is to bring fault tolerance and fault isolation, and that it needs to get thoroughly tested before the conclusion of this project.

Reviewer 2:

The reviewer commented that the first budget period of the project was dedicated to system development including identification of a test site, and that the second budget period was utilized for system integration including test site preparation and validation of a protection system for the XFC prototype. The reviewer added that budget period three activities are targeted for system deployment of 1 MVA XFC. The reviewer explained that dual active bridge (DAB)-based SST architecture was defined for direct interface of XFC with 13.2 kV line-to-line electric grid, and that the SST module design was completed including its thermal management system. The reviewer noted that SST efficiency was evaluated including the efficiency of various components over power range from 5 kW to 55 kW. The reviewer said that SST is under test in the North Carolina State University (NCSU) laboratory, and the distributed DC charging concept was illustrated in ELT238 project's AMR report. The reviewer added that the performance of a solid-state circuit breaker (SSCB) was evaluated, and sample test results were included in the ELT238 project's AMR report. The reviewer noted that the system level protection tests passed with one fault at a time and the faulty portion was successfully separated from rest of the XFC system. The reviewer remarked that the XFC system domestications were planned, however subject to approval from NYPA, and that the test site layout is included in the ELT238 project's AMR report.

Reviewer 3:

The reviewer observed that much of the presentation is the same as the 2022 presentation, including budget, accomplishments, plan to complete, and plan to submit a no-cost time extension. The reviewer added that the speaker's presentation was very informative and described the development, testing, integration, and refinement process that has been applied to all project aspects. The reviewer stated that the project innovations and results are very impressive including the smaller system footprint, volume, and mass, with higher power, higher efficiency at lower system-level cost. The reviewer commented that the SSCB fault current performance of 10–100 micro-seconds is impressive, and that all reported component and system testing was passed. The reviewer mentioned that a demonstration system is developed into a shipping container enclosure and being installed at a NYPA site for testing.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer stated that there is an acceptable group of collaborators that have been working well with each contributing their respective strengths and designed roles. The reviewer thought that the selection of ABB and New York Power Authority (NYPA) are great partners for this project. The reviewer suggested that the team could be enhanced with the addition of one of the strong power electronics national laboratories, but the project is executing to plan without it.

Reviewer 2:

The reviewer remarked that a strong collaboration exists in execution of project activities and multiple entities are involved in the NCSU-led project.

Reviewer 3:

The reviewer commented that NCSU Freedom Center's lead for project innovations and leadership appears to be strong. The reviewer added that ABB's leading high-power electrical, power electronics, and charging station development and manufacturing has been a great inclusion in the project. The reviewer said that NYPA is an ideal test and evaluation partner, and as a self-permitting entity, is streamlining the demonstration phase installation and testing.

Question 4: Please comment on the 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 did not see any future research suggested for this project, aside from wrapping up the install and testing of the existing project.

Reviewer 2:

The reviewer remarked that there was no data included in report. The reviewer added that this is the last budget period, with only one major task incomplete, which is the verification of 1 MVA XFC at test site in New York.

Reviewer 3:

The reviewer observed that future work will install the prototype system at the NYPA facility and demonstrate and evaluate the performance.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer commented that the project presents a usable framework for potential lower operating cost and installation cost for extreme fast charging networks from a medium voltage distribution. The reviewer added that this can help to accelerate charging infrastructure.

Reviewer 2:

The reviewer stated that this project is relevant to VTO sub-program in the electrification area and will accelerate adoption of EVs by increasing the availability of XFC to HD and light-duty vehicles and utilities will feel comfortable in allowing XFC interface with medium voltage (MV) grid.

Reviewer 3:

The reviewer noted that the project is developing an innovative approach to significantly reduce the size, cost, installation cost, and operational flexibility of banks of high-power DCFC equipment. The reviewer added that this is a critical need given the country's and world's rapid and concurrent transition to electrified transport.

The reviewer stated that having electric vehicle supply equipment (EVSE) manufacturer ABB involved with a strong project role increases the relevance rating since it is more likely to be used or leveraged for commercial applications.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer did not think that there have been or will be issues on project resources, unless they have far underestimated the planned installation.

Reviewer 2:

The reviewer stated that the project has necessary resources and research funds.

Reviewer 3:

The reviewer mentioned that bringing unique expertise together for a project like this is not trivial. The reviewer explained that the high-level funding description in the presentation seems like a good balance of funding and cost share to accomplish the project with a reasonable budget.

Presentation Number: ELT239
Presentation Title: High-Power Inductive Charging System Development and Integration for Mobility
Principal Investigator: Omer Onar (Oak Ridge National Laboratory)

Presenter

Omer Onar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of 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.

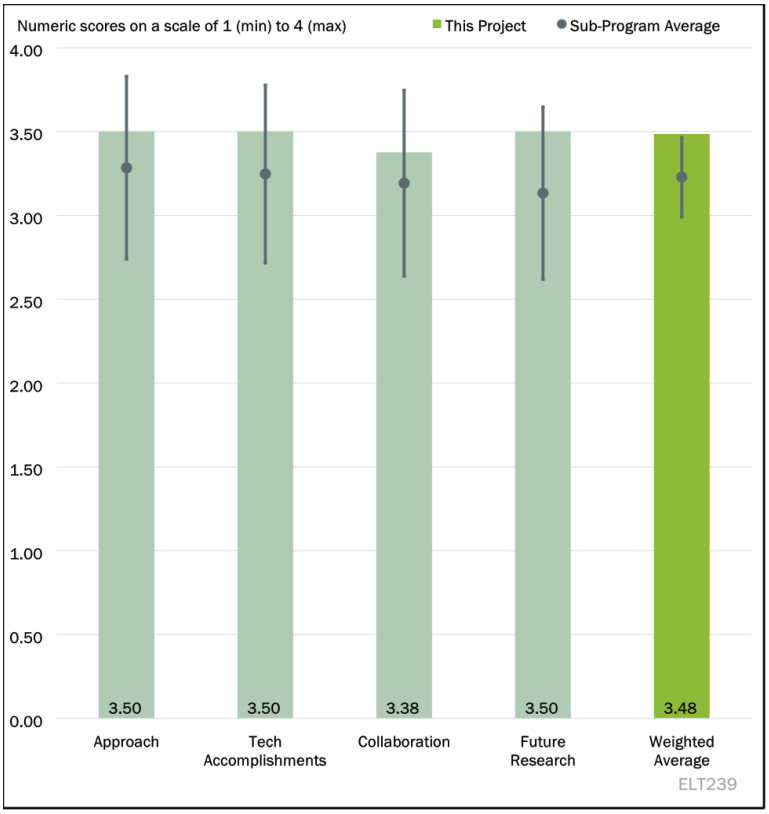

Figure 2-14 - Presentation Number: ELT239 Presentation Title: High-Power Inductive Charging System Development and Integration for Mobility Principal Investigator: Omer Onar (Oak Ridge National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer said that the project team sought to develop a high-powered inductive charging system and has done so for 100 kW—20 minutes to full charge—and is currently working on integrating the 270 kW version for the Porsche. The reviewer added that the project design is thorough and has proven a successful path to the development of this charging system. The reviewer noted that the timeline planned is reasonable; however, more time refining and testing will need to be done beyond the dates of this project to reach the marketable stage.

Reviewer 2:

The reviewer remarked that the approach covers system design, modeling, and simulation of the grid interface, and testing in the laboratory and in vehicle validation.

Reviewer 3:

The reviewer observed that the project is nearly complete. The reviewer added that the presentation detailed the project approach from modeling to component development and validation, to subsystem and system development and validation, and finally full-scale demonstration bench then vehicle. The reviewer stated that the schedule to achieve this was realistic and the project remained on track, at least at the budget period-level as reported). The reviewer noted that the more than 94% efficiency exceeds the 90% target. The reviewer

commented that the barriers and objectives mentioned "Maintaining high power quality on the grid side (less than or equal to 5% on current harmonics, greater than or equal to 95% input power factor)," but that neither was mentioned in the presentation.

Reviewer 4:

The reviewer stated that the approach is well known and established in previous and similar research projects.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer said that with just months left in this project, the team has completed nearly all milestones, and are working on the 270 kW integration, testing, and demonstration. The reviewer added that the team met its greater than 90% operating efficiency goal thus far. The reviewer noted that, as indicated in the presentation, refining of the prototype continues and it is anticipated that development of this charging system will not end at the project end date. The reviewer stated that in all probability, there will be more work done here outside of this 5-year project. The reviewer commented that with these successes, there will be more testing and validation, particularly in real-world conditions, and the designing of enclosures, before this product is marketable.

Reviewer 2:

The reviewer observed that significant technical accomplishments include: completing inverter design with 55 kW/L power density; designing vehicle-side rectifier; completing ground and vehicle coupler designs and developments; finalizing coupler specifications; and performing experimental testing of the 100 kW system with overall efficiency exceeding 94%.

Reviewer 3:

The reviewer mentioned that the project remained on schedule and achieved very good power transfer performance with higher efficiency than targeted. The reviewer said that different coil winding approaches were investigated to maximize performance and tradeoffs. The reviewer observed that barriers and objectives of "Maintaining high power quality on the grid side (less than or equal to 5% on current harmonics, greater or equal to 95% input power factor)" were not discussed in the presentation. The reviewer added that thermal management was mentioned as a challenge in the 2022 and 2023 presentations. The reviewer stated that the final steps of the 270 kW system integration and demonstration and addressing thermal and electromagnetic interference (EMI) issues will be completed by the project close.

Reviewer 4:

The reviewer stated that the project team still needs to evaluate and test in real world conditions.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer stated that the presentation clearly indicates the roles of each of the team—national laboratory and two EV OEMs. The reviewer had no doubt that each partner brought 110% to the project as the development of an inductive charging system is a game changer for all parties involved. The reviewer concluded that as a team, they have the skills to make it happen.

Reviewer 2:

The reviewer commented that ORNL's project partners include two large automotive manufacturers in Hyundai-Kia America Technical Center and Volkswagen Group of America's Innovation Hub.

Reviewer 3:

The reviewer remarked that the coordination between ORNL and the OEM partners, Hyundai and Volkswagen, and the roles of each, with ORNL as the clear lead, were well described and logical. The reviewer added that Hyundai supported the vehicle and battery management system integration (100 kW system). The reviewer noted that Volkswagen did the same for the Porsche demonstrator (270 kW system), but the collaboration is more in-depth to understand how to move this in the future to a commercial product for manufacturing, cost, packaging, etc. that is important for commercialization. The reviewer stated that the presenter also noted several related wireless charging projects that involved other vehicle OEMs, as well as mentioned discussions are being held with other OEMs. The reviewer observed that the actual commercial interest in the topic and project is key to justify the current and potential future funding for wireless charging research.

Reviewer 4:

The reviewer stated that collaborations seem to be fine, with nothing being extraordinary.

Question 4: Please comment on the 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 presentation indicates as future work: "Perform vehicle integrations for demonstrations for 270 kW power level on Porsche Taycan research vehicle." The reviewer noted that there is no doubt that future work will occur, and this product's development will move forward.

Reviewer 2:

The reviewer commented that future research is appropriate as it includes completion of a 3-year budget period by Sept. 2023 to complete system integration and installation into a vehicle to validate 270 kW power transfer.

Reviewer 3:

The reviewer stated that the proposed future research clearly addresses the few remaining items of the scope, including thermal management, EMI, and integrating and testing the 270 kW system on the Porsche Taycan.

Reviewer 4:

The reviewer recommended having a detailed design validation plan and report (DVP&R) driven by requirements and real-world test conditions.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that the development of this product affects all subprograms listed above, particularly Batteries, Electrification and Energy Efficient Mobility Systems. The reviewer added that inductive charging is the next step in fast charging, with the potential to fast-track widespread EV adoption.

Reviewer 2:

The reviewer noted that the project is relevant to the VTO Electrification subprogram as it is designing and developing a plug-less extreme fast charging system that would enable faster and broader transportation electrification.

Reviewer 3:

The reviewer remarked that the Electrification Technologies (ELT) subprogram objectives in the linked Annual Progress Report focus on power electronic and electric motor cost (dollar/kilowatt) and power density (kilowatt/liter). The reviewer noted that the project's power electronics development resulted in a power

density of 54.58 kW/L, exceeding the DOE 33 kW/L 2025 target. The reviewer added that the objectives do not specify wireless charging surface power densities (kilowatt/square meter) but Slide 9 of the 2022 presentation showed the significant increase from approximately 250 kW/m^2 to 1.5 MW/m^2 (vehicle side). The reviewer commented that the cost was not mentioned which will be critically important if this were to be offered on commercially available vehicles. The reviewer mentioned deeper collaboration with Volkswagen to understand how to further develop the prototype development into a potential commercial product at an OEM or tier supplier level.

Reviewer 4:

The reviewer observed the potential applications in fleets and public charging stations.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that the presenter did not indicate the resources were insufficient to achieve the stated milestones; however, for this charging system to be marketable, much more testing and refining needs to be done, as stated in the presentation.

Reviewer 2:

The reviewer noted that the total project funding over a 5-year period of performance is $5.2 million of which DOE share is $2.2 million. The reviewer added that this funding amount seems appropriate for the proposed scope and approach of the project.

Reviewer 3:

The reviewer mentioned that the project involves component development like modeling and prototype hardware and software, testing, and vehicle integration work. The reviewer concluded that the funding level seems to be in line with the work included in the scope and the work that has been completed.

Reviewer 4:

The reviewer had nothing to note.

Presentation Number: ELT240
Presentation Title: Wireless Extreme Fast Charging for Electric Trucks (WXFC-Trucks)
Principal Investigator: Ryan Calder (WAVE, Inc.)

Presenter

Ryan Calder, WAVE, 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, 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.

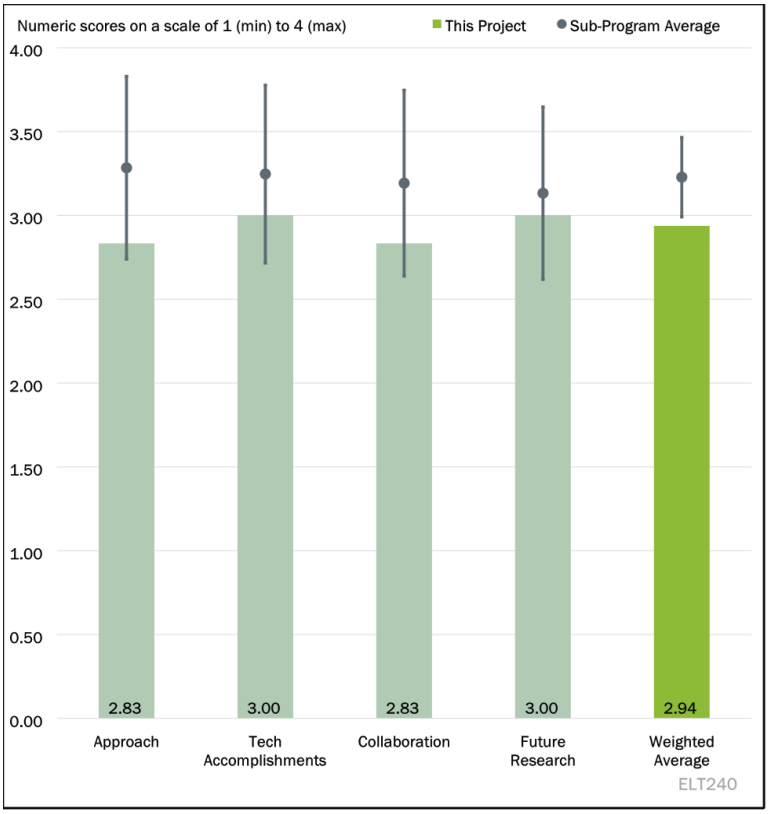

Figure 2-15 - Presentation Number: ELT240 Presentation Title: Wireless Extreme Fast Charging for Electric Trucks (WXFC-Trucks) Principal Investigator: Ryan Calder (WAVE, Inc.)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer commented that this expands the options for wireless power transfer (WPT) to the highest level identified in the standards and addresses the design, installation and system testing and some site issues. The reviewer noted that additional site options should be included to include more use cases that need to address challenges of this power level being used for multiple stations.

Reviewer 2:

The reviewer observed that the project briefing lists the following barrier: "Meeting the window of time to deliver a medium voltage feed to the charge site." The reviewer added that the project team has been unsuccessful in addressing this barrier and the project is in its final year of the project plan.

Reviewer 3:

The reviewer noted that the project is well designed for the total cost and expected work. The reviewer said that the timeline is an issue as delays in materials and siting permissions have lost the project valuable time. The reviewer declared that the overall milestones and corresponding budget period in which the milestones would be completed seem reasonable except for Task 6: 500 kW system deployment. The reviewer stated that while the timeline for this task spans all three budget periods, the project has less than six months to go, and the system still has not been deployed. The reviewer observed that the presenter was asked how the project team is addressing this barrier and responded with an answer that said that the testing would still span the

original six months planned, though the reviewer was uncertain how this will happen unless there is a no-cost extension to the project.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that the results identify that the goals are being met with charge rates and duration.

Reviewer 2:

The reviewer stated that this project appears to have accomplished some piecemeal testing of components but has been unable to create and demonstrate the original vision of a fully integrated MV grid connection with step-down to 500 kW wireless charging system at the port of Los Angeles facility that is used in a 2-year demonstration to charge two Class 8 trucks.

Reviewer 3:

The reviewer remarked that the technical accomplishments and progress have been affected by material and siting permissions delays but most assembly has been completed and testing of the unfolder, enclosures, transformers, and cabinet has begun. The reviewer declared that no unexpected issues seem to have come up. The reviewer added that software and control development on the low power prototypes appear to work as expected and demonstrated close to 50% reduction in total harmonic distortion.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer noted that the project has a sufficient mix of partners and good participation to meet goals, timing, and budget.

Reviewer 2:

The reviewer stated that testing accomplishments indicate some level of collaboration between partners but the lack of fully integrated demonstration suggests that collaboration could be improved.

Reviewer 3:

The reviewer observed that on the industry side, TTSI, the port trucks partner, has not seemed reliable, since the overall project team is unable to do site deployment according to their original timeline. The reviewer added that while the presenter indicated the project team would be seeking out another port partner, it is very late into the project period to be needing to make the switch and onboard a new ports partner. The reviewer did not attend the AMR last year and was uncertain why Wireless Advanced Vehicles Electrification (WAVE), the project lead, waited so long before connecting with TTSI about the port location and permissions there.

Question 4: Please comment on the 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 more data from site variations could be used. The reviewer added that access to medium voltage issues at other sites needs to be included. The reviewer commented that additional testing for EMC/EMF and other factors could be included.

Reviewer 2:

The reviewer noted that future work listed is appropriate to complete the revised work plan.

Reviewer 3:

The reviewer expressed that future work is based on deploying the wireless charger and truck and demonstrating the AC/DC converter and seems reasonable to finish out the project. The reviewer added that future work will likely achieve its targets, just not on the original timeline, which was to run the demonstration for six months and collect required data.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer indicated that vehicles using higher power wireless charging offers a means for hands-free charging along with options for AC and DC charging.

Reviewer 2:

The reviewer confirmed that the project supports the overall VTO subprogram objectives to develop high power charging technologies for HD EV charging.

Reviewer 3:

The reviewer noted that the project is relevant to all categories of VTO. The reviewer added that the project focuses on creating better HD EVs through fast wireless charging. The reviewer stated that materials are affected by what the wireless chargers are made out of, and the electric powertrain created specifically for this project by Cummins as well as the auto charge testing system, and creation of custom thermal management for cell fast charging. The reviewer reported that Energy Efficient Mobility Systems can review the data from the bus wireless charger and gain insight into efficiencies and improvements in existing mobility systems. The reviewer remarked that since there is a custom Cummins electric powertrain, the advance engine and fuel technologies category is covered, as well as electrification and analysis through the final deployment and data collection.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that partners are well versed with the technology and effective to apply previous systems to this higher power approach.

Reviewer 2:

The reviewer said that it appears that the timeline allocations and the planning resources for this project were insufficient since the project plan was not executable in the planned timeframe. The reviewer indicated that it is clear that the budget was not sufficient to overcome the issues that were encountered.

Reviewer 3:

The reviewer expressed that for the total budget of the project, the resources seem sufficient for the project to achieve all their stated milestones in a timely manner; however, due to supply chain delays and site permissions delays, there will have to be a no-cost time extension to get the deployment and testing validated. The reviewer added that the amount of resources should have facilitated no time delay, but due to the project timeline spanning the Covid pandemic and the subsequent resource and supply chain delays, the project seems as on schedule as it could hope for.

Presentation Number: ELT252
Presentation Title: Wound-Field Synchronous Machine-System Integration toward Increased Power Density and Commercialization
Principal Investigator: Lakshmi Iyer (Magna Services of America, Inc.)

Presenter

Lakshmi Iyer, Magna Services of America, Inc.

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. 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.

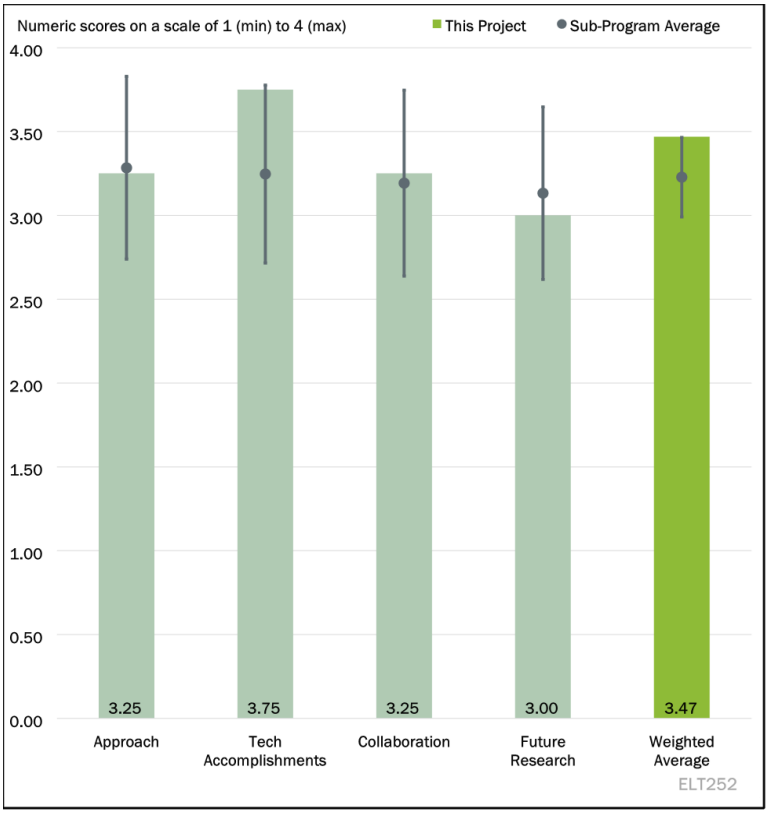

Figure 2-16 - Presentation Number: ELT252 Presentation Title: Wound-Field Synchronous Machine-System Integration toward Increased Power Density and Commercialization Principal Investigator: Lakshmi Iyer (Magna Services of America, Inc.)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer noted the nice work exploring novel motor design and the high potential for translation from university to industry.

Reviewer 2:

The reviewer stated that the investigators have done a very good job of looking at the design tradeoffs (cooling, manufacturing costs, etc.); however, using a World-Harmonized Light-Duty Vehicle Test Cycle (WLTC) based cycle for measuring efficiency could provide rather optimistic estimates of the e-machine performance. The reviewer added that using more aggressive cycles, specifically, the EPA 5-cycle may have given a better indication of the operating efficiency. The reviewer expressed that it would have also been good to understand if the optimization process yielded significantly different design choices when optimized with respect to a different set of drive cycles. The reviewer observed that it is understandable that standard drive cycles have to be used to evaluate the efficiency of these machines, but that no real customer drives these standard drive cycles, and some idea of how good the machine performs in real world conditions would be very helpful. The reviewer commented that another point that comes to mind is that the machine is designed to be operated at 400V nominal. The reviewer reported that most OEMs appear to be moving towards 800V in the near future, and an understanding of how much benefit that could have provided in terms of efficiency would have been helpful as well. The reviewer remarked that it would also have been good if the relative

merits of brushless field excitation and brushed field excitation were explored, but it is understandable that it was not part of the scope because there is nothing novel in brushed excitation.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer acknowledged that the project seems to be on track.

Reviewer 2:

The reviewer observed that it appears that Magna has reached a stage in the development where it is ready to put this design into serial production, which is a good indication of the project's success.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer would like to see more industry leadership, and it appears that the most critical parts are done within the university.

Reviewer 2:

The reviewer stated that considering that the scope of the project was to develop a wound-field synchronous machine (WFSM), the choice of team members could not have been better, since both Illinois Institute of Technology and University of Wisconsin-Madison have had a history of working on wound field synchronous machines with inductive or capacitive excitation.

Question 4: Please comment on the 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 it looks like they are wrapping up in 2023.

Reviewer 2:

The reviewer noted that the project has been completed.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer said it was relevant to Electrification.

Reviewer 2:

The reviewer affirmed that from an OEM perspective, while the little bit of hit that will be taken because lower torque density is not desirable, the lower carbon footprint, supply chain reliability, etc., is very desirable. The reviewer reported that this approach does not provide a significant cost advantage over "conventional" integrated power module (IPM) designs. The reviewer added that if these get to a point where they offer a cost advantage over conventional IPMs, then the impact of this technology would be far more significant.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the project is ending so there is no need to adjust anything. The reviewer would like to see these types of projects to go over $1 million.

Reviewer 2:

The reviewer noted that the project has been completed.

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, Charlotte)

Presenter

Somasundaram Essakiappan, QM Power, 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, 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.

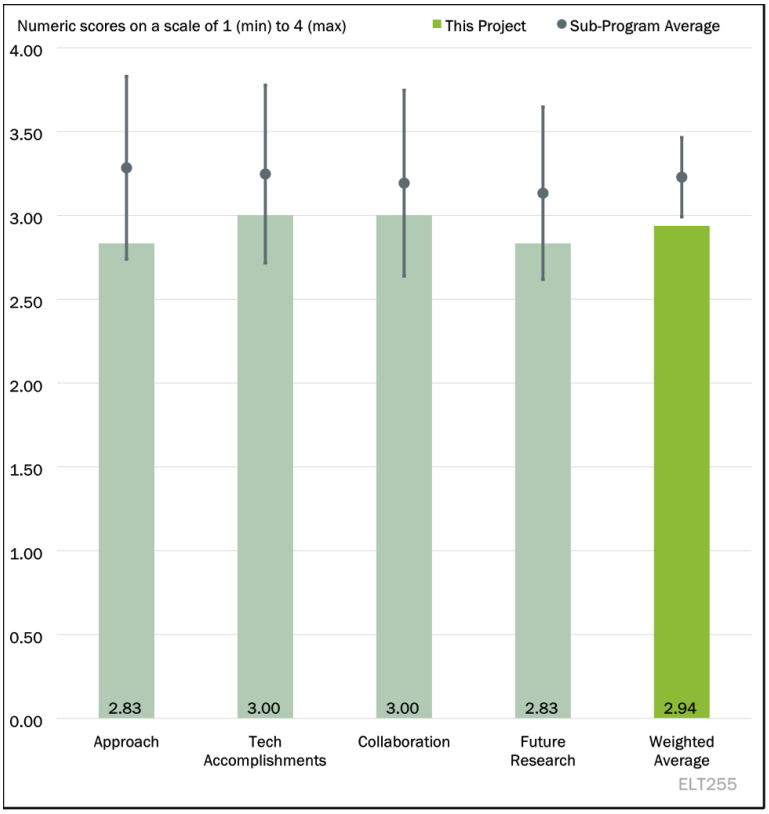

Figure 2-17 - Presentation Number: ELT255 Presentation Title: Cost-Effective, Rare-Earth-Free, Flux-Doubling, Torque-Doubling, Increased Power Density Traction Motor with Near-Zero Open-Circuit Back-Electromagnetic Field and No-Cogging Torque Principal Investigator: Jim Gafford (University of North Carolina, Charlotte)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer remarked the project seems to be addressing and advancing towards overcoming the barriers.

Reviewer 2:

The reviewer commented since the project is timed to end in June 2023, the reviewer has not seen the quantified benefits of this project. Testing on a bench or dynameter was not well demonstrated.

Reviewer 3:

The reviewer said it is hard to draw conclusions regarding the performance of the proposed system with detailed test results as well as a quantitative comparison to a well-established baseline. Also, is the reported power density based on active material or total motor size?

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer remarked the project highlights good results and accomplishments.

Reviewer 2:

The reviewer said targets and objectives were not quantified in terms of actual performance in real world applications.

Reviewer 3:

The reviewer commented more complete test results including efficiency measurement are needed. Also, some cost estimate and information about magnet content should be provided.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer noted the team seems to be a small and efficient team. Good choice.

Reviewer 2:

The reviewer remarked a path toward commercialization was not demonstrated.

Reviewer 3:

The reviewer commented there seems to be good collaboration between participating organizations.

Question 4: Please comment on the 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 it seems like the team has plenty to do.

Reviewer 2:

The reviewer said the objective for cost reduction was not presented.

Reviewer 3:

The reviewer recommended more detailed experimental results are needed.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer agreed the project is relevant in terms of trying to meet the DOE targets.

Reviewer 2:

The reviewer noted the project is focusing on electrification.

Reviewer 3:

The reviewer noted this type of technology is widespread among key power electronics suppliers and it is becoming a commodity for electrified applications.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer would expect these projects to be over $1 million.

Reviewer 2:

The reviewer said the project seems to be sufficient for the scope of work.

Reviewer 3:

The reviewer found that resources are sufficient based on scope.

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 Trucks)

Presenter

Teresa Taylor, Volvo Trucks

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.

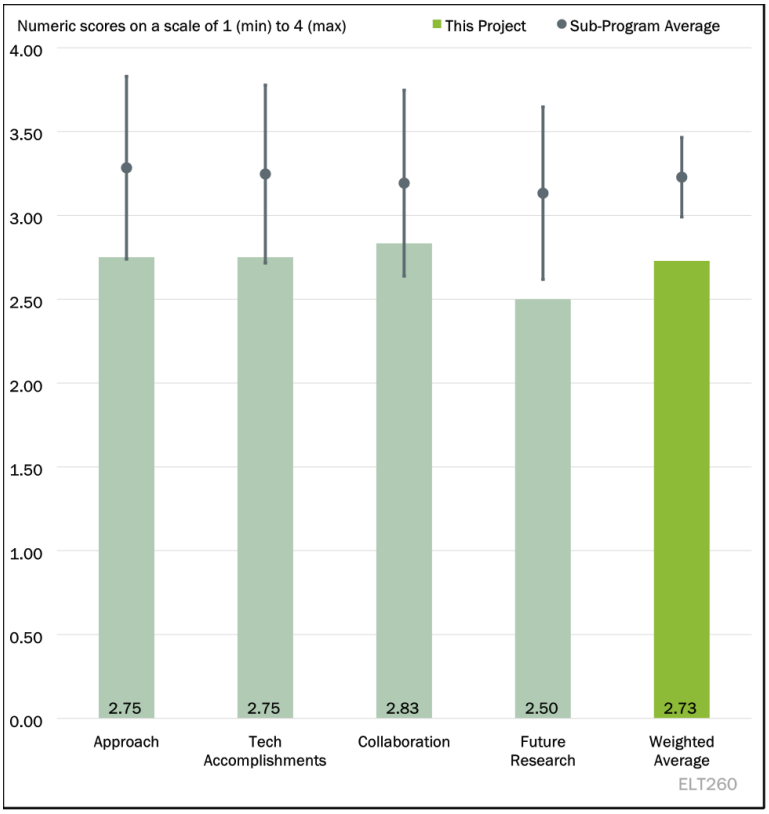

Figure 2-18 - Presentation Number: ELT260 Presentation Title: Improving the Freight Productivity of a Heavy-Duty, Battery Electric Truck by Intelligent Energy Management Principal Investigator: Teresa Taylor (Volvo Trucks)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer commented it does not seem to be a well-managed project. The reviewer did not see much of "new" things from last year, and University of Minnesota appears to be doing all the work.

Reviewer 2:

The reviewer said it is unclear how the proposed work will validate the improvements relative to other tools which may be available and as compared to the baseline of status quo. This should be made clear and must consider real-world application and benchmarking in some form.

Reviewer 3:

The approach was good for this project. Having said that, the reviewer is not convinced of the execution.

Reviewer 4:

The reviewer said the project is updated from actual data but may not address variations to vehicle weight as lighter versus heavier loads are included. Optional routes may not be as effective if destinations are shorter distances and vary daily.

Reviewer 5:

The reviewer said this project addresses Improving the Freight Productivity of a Heavy-Duty, Battery Electric Truck by Intelligent Energy Management. The barriers that were considered were TCO including the high

purchase price and range of charge and payload, lack of valid performance and reliability data on battery electric trucks in real-world usage, and infrastructure planning and costs. The 3-year project was designed to first understand the fleet partners' baseline operations and establish project duty cycles and then develop a physics-based truck model that would combine battery information, utility demand charges, and database parameters as inputs to a machine learning algorithm that will predict energy use, operational energy cost, and battery performance. Implement an intelligent energy management system installed on two battery EVs using a low low-distraction screen to display charging and routing recommendations to operators along with vehicle charging stations at fleet partners' locations. The reviewer said a final analysis of the data generated was used to compare battery electric trucks and validate the intelligent energy management system for an extended mileage range. This is considered an outstanding approach to addressing the barriers identified.

Reviewer 6:

The reviewer noted the major problems still to be attacked in this project are as follows: (1) determine the mass of the actual payload—this is critical for the algorithm for the intelligent energy management system (i-EMS) to work; (2) take into account real-time traffic conditions, detours, and routing changes, and (3) feasibility/ viability of the driver-vehicle interface (DVI) is critical for reducing range anxiety). The reviewer said the project also failed to take into account the amount of time for in-route charging; although this is controlled by the charging management system, it has to be factored into the total cost of operation because the driver has to be paid while waiting for the charging to be completed. Emissions reduction should never have been an issue in this project.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer remarked the project is progressing satisfactorily relative to overall plans. No lapses in technical progress relative to planned milestones are identified.

Reviewer 2:

The reviewer observed some good accomplishments; however, the project is lacking highlights of the latest updates (i.e., What's new?). The reviewer noted the project is going to end soon, no need to correct the course.

Reviewer 3:

The reviewer said there are many deliverables yet to be completed—and this team is now out of time—as the project ends this month. The calculation to determine mass appears to have worked very well.

Reviewer 4:

The reviewer said results are early since vehicles and charging equipment have not been fully implemented.

Reviewer 5:

The reviewer said one technical accomplishment was the development of a physics-based model that included algorithms for road load and battery capacity management. The model was tuned for the best fit of available trip data for regenerative braking, auxiliary power, and overall trip efficiency. The model is capable of predicting linear travel range assuming similar energy consumption and charging needs including average energy consumption (kilowatt-hour/mile). The reviewer noted the team used recurrent neural networks to predict energy needed to complete route and trained using historical driving data and route information. The team also used mass prediction to monitor energy consumption for both the observed and modeled conditions. An economy toll estimation was developed by matching global positioning system trajectories to paths in a road network graph which provided travel features on each segment of road network graph. The reviewer said an energy efficient routing pathfinding algorithm was developed that used a physics-informed heuristic

approach with pre-calculated energy consumption for all segments in all situations. The algorithm supported multi-destination routing and accounted for road restrictions, which is better than the current state-of the-art models that attempt to do this. Another technical accomplishment was to determine the placement of charging station for commercial fleets by collecting driving data for existing fleet routes, simulating the fleet routes using the tuned battery EV model, predicting the charging demand along the road network, and optimizing the charger sizing and placement to meet charging demand considering time, cost, and route coverage. An operational cost model was also developed that contained data for fixed costs, materials, charger hardware, electrical hardware, variable costs, labor and maintenance, taxes and permit fees, energy, the number and cost of trucks, the number and cost of chargers, and the energy costs (electricity or fuel). This is considered to be a very comprehensive model for the application to battery EVs. All these technical accomplishments are considered to be significant contributions to further the acceptance of EVs.

Reviewer 6:

The presentation points out that 80% of the project has been completed, but honestly, absolutely no milestones were given so it is impossible to determine whether 80% of the tasks or effort required to complete the project have actually been completed. Considering the fact that the end date of the project is June 2023 (two weeks away), the in-route charging equipment has not been installed in the second location (Texas), the Texas data has not been collected yet, this project is behind schedule. With an end date of June 2023 and start date of October 2019, the project should have been more than 90% completed.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer remarked the collaboration included academia (University of Minnesota), an EV charger supplier (Gilbarco), and two fleet operators (HEB Companies and Murphy Logistics) led by the original equipment operator (Volvo). This is considered excellent collaboration for the purpose of generating real world data that was used in the model development that will be beneficial to the manufacturers and operators.

Reviewer 2:

The reviewer liked the fact that an actual trucking company is demonstrating or testing the battery-electric tractors as well as the field i-EMS algorithm. The reviewer also appreciated the fact that the drivers were interviewed about how they like the battery-electric trucks and about range anxiety.

Reviewer 3:

The reviewer noted that the University of Minnesota appears to be doing the majority of the work.

Reviewer 4:

The reviewer remarked team collaboration needs to be demonstrated more clearly. Specific contributions of partners are not clearly demonstrated.

Reviewer 5:

The reviewer noted that when a project is running this far behind schedule, one has to wonder if a lack of coordination is partly to blame.

Reviewer 6:

Fleet partners should be included to provide a variation of feedback on results.

Question 4: Please comment on the 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 project is ending soon, so future work is somehow less ambitious. Also, the project appears to be more complex than the team can handle.

Reviewer 2:

The reviewer said proposed future research should increase validation with focus on real-world conditions.

Reviewer 3:

The reviewer found that the proposed future work is in line with the original project plan. Having said that, the reviewer did not see how this can be completed within the original timeframe.

Reviewer 4:

The reviewer pointed out that more locations with variations on loads, terrains, traffic, etc. will broaden the data model.

Reviewer 5:

The reviewer commented that although the project has ended, the proposed future research recommended extending test routes with the addition of an on-route charging station, demonstrating a capability to achieve 250+ miles of daily driving, evaluating eco-routing algorithms for test routes, finalizing the cost model and evaluate the return on investment and emission reduction, and evaluating the impact of extreme ambient conditions (hot summer and cold winter geographical locations) on performance. These seem to be reasonable follow-on efforts to this project.

Reviewer 6:

The reviewer commented the principal investigator still needs to address the mass (payload) determination, dynamic re-routing due to traffic, detours and construction, and suitability of the DVI. Emissions reduction should never have been an issue.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer remarked there are very few projects for HD battery EVs, so this project is commendable.

Reviewer 2:

The reviewer noted the project's relevant to Analysis and Electrification.

Reviewer 3:

The reviewer said the basic program objectives are satisfied.

Reviewer 4:

The reviewer commented the project scope is certainly relevant to VTO objectives. The reviewer was just not sure the project completed enough of the original objectives to offer much new technical knowledge.

Reviewer 5:

The reviewer remarked this project provides initial input to the data required.

Reviewer 6:

The reviewer said this project fully supports the Electrification R&D Grid and Charging Infrastructure program's mission to conduct early-stage research and development on transportation electrification technologies that enable reduced petroleum consumption by light-, medium-, and HD vehicles.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said for what was done the funding appears to be sufficient.

Reviewer 2:

The reviewer said resources for this project were aligned well with the original project scope.

Reviewer 3:

The reviewer said this project was funded $4.9 million over a 4-year period or more than $1 million per year with a 25% cost share by industry. The companies involved for the funding allocated provided sufficient resources for the work required.

Reviewer 4:

The reviewer recommended variations to charger sizes at various locations are needed because 150 kW is the low end of the power expected.

Reviewer 5:

The reviewer commented project resources appear higher than would be expected but the industrial cost share does offset some concerns.

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. 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.

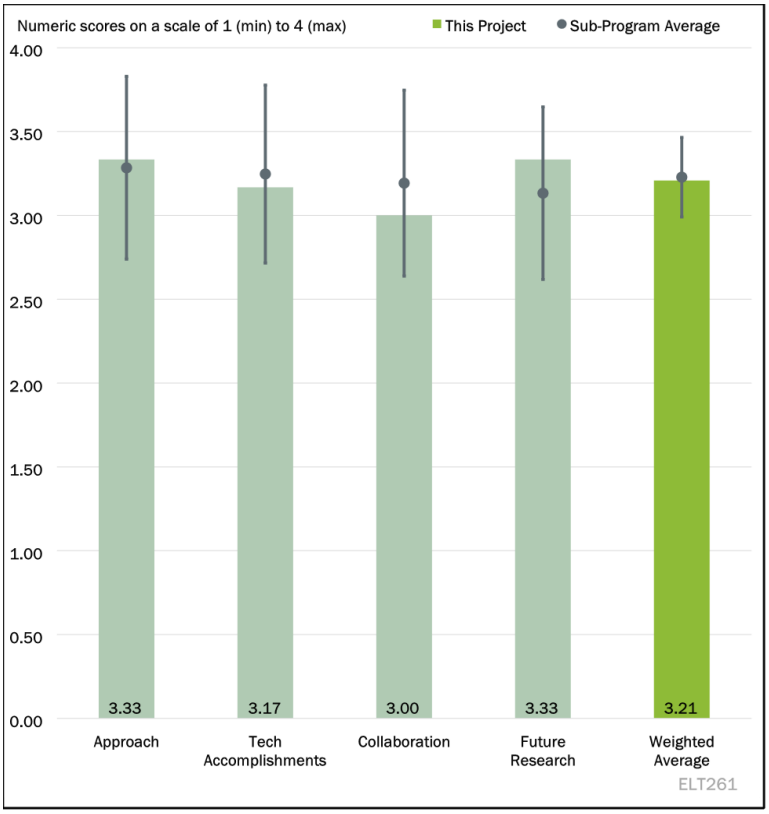

Figure 2-19 - Presentation Number: ELT261 Presentation Title: High-Efficiency Powertrain for Heavy-Duty Trucks using Silicon Carbide Inverter Principal Investigator: Steve Peelman (Ricardo)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer remarked attention to the performance and efficiency of electric drive components is valid and important to achieve maximum feasible range/cost from energy storage system (ESS) and reduce overall energy consumption costs. The evidence of project outcomes would be improved when vehicle level results of ton-miles/kWh are presented and compared to the baseline.

Reviewer 2:

The reviewer commented the project report outlines a logical and appropriate approach to execute project tasks targeted for the successful completion.

Reviewer 3:

The reviewer remarked the project does not appear to be addressing major technology challenges. This project is more on a demonstration side.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer said that the development and tests of the new inverter, with data shown, are significant. The presentation would be stronger with short notes on the key technical aspects of the SiC inverter that made it more efficient than the baseline inverter. This was probably shown in detail in prior years, but a short review

would be constructive here. The reviewer recommended the baseline technology should be clarified, and how long the SiC inverter has been used in this application should be mentioned.

Reviewer 2:

The reviewer said cannot really point out anything going above or beyond what was promised. The project is mainly addressing component development.

Reviewer 3:

The reviewer remarked the packaging improvements for inverter power stage has led nearly 3% improvements in partial power efficiency, which is significant as majority of the time SiC and even Si insulated gate bipolar transistor (IGBT) inverter in vehicles operates at partial load. Motor is characterized in back-to-back motor dynamometer. The reviewer reported that the current controller was tuned for faster dynamic response over the loading condition of the SiC inverter and that five vehicles are built for testing.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer commented that excellent collaboration exists in executing the project activities.

Reviewer 2:

The reviewer said the project partners are shown as having complementary roles, but details are not strong. It is not clear which if any partners are in business of large-volume production of inverters. The reviewer said further explanation is needed.

Reviewer 3:

The reviewer noted that it looks like North Carolina State is doing a lot of work, but the overall collaboration appears to be going well.

Question 4: Please comment on the 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 continuation of the project to an on-road assessment is appropriate and presented adequately. The presentation of the significant remaining challenges indicates high degree of team strength.

Reviewer 2:

The reviewer commented that the project is wrapping up so no need to direct any further.

Reviewer 3:

The reviewer said this project is about to conclude, and a project report included future research task and topics, which are relevant and appropriate for remaining time in the project, which may be no-cost extension-type situation.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer remarked that the improvement of electric drive component and system efficiency is highly relevant to making EVs cost competitive for an accelerated decarbonization strategy.

Reviewer 2:

The reviewer noted the project focuses on electrification.

Reviewer 3:

The reviewer commented that this project is relevant to VTO sub-program in electrification area and will accelerate adoption of on-road HD such as trucks and buses.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said it would be useful to present the funding distribution among the partners.

Reviewer 2:

The reviewer commented that the project is about to wrap up. The 20% cost share is a very good ratio for this kind of development project, which could have been funded internally.

Reviewer 3:

The reviewer pointed out that the project PI is planning to request no-cost extension and the project has necessary resources and research funds.

Presentation Number: ELT262
Presentation Title: Long-Range, Heavy-Duty Battery-Electric Vehicle with Megawatt Wireless Charging
Principal Investigator: Ryan Reed (Kenworth)

Presenter

Ryan Reed, Kenworth

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.

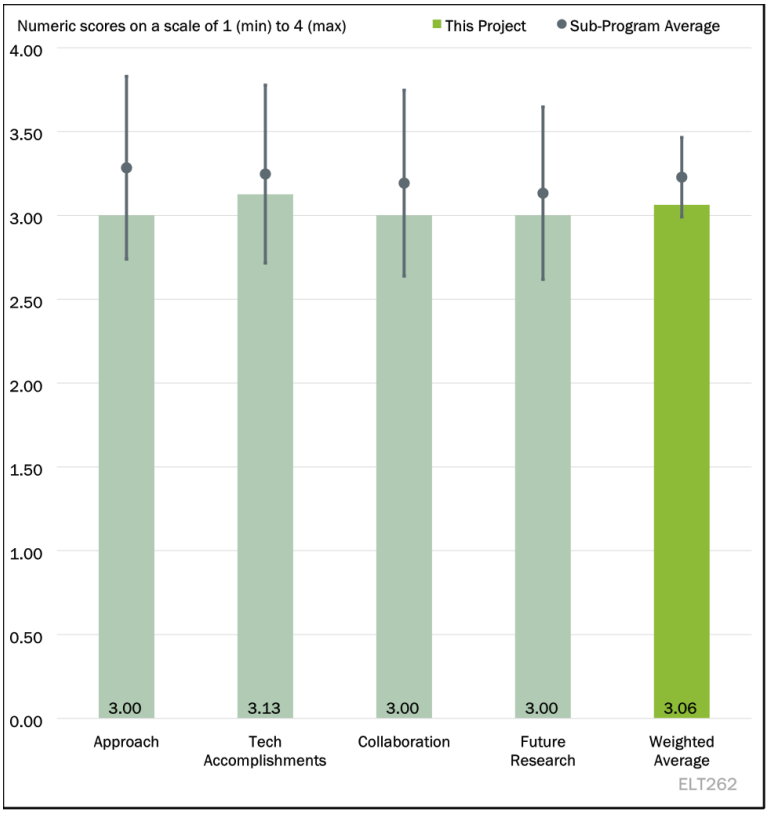

Figure 2-20 - Presentation Number: ELT262 Presentation Title: Long-Range, Heavy-Duty Battery-Electric Vehicle with Megawatt Wireless Charging Principal Investigator: Ryan Reed (Kenworth)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer said the goals and timeline of this project are well designed and in support of not only DOE goals, but customer goals and expectations for battery electric trucks.

Reviewer 2:

The reviewer stated comprehensive approach focusing on the wireless megawatt charger followed by truck design to incorporate megawatt charging technology and a 3-month test of the system in the fleet to demonstrate capability of 400-mile two shift operation.

Reviewer 3:

The reviewer noted this project is already in year four of a 5-year project. There have been many setbacks resulting in delayed deliverables. The reviewer said it appears that some of the initial work was likely slow getting started, pushing many deliverables to the end of the 5-year timeframe.

Reviewer 4:

The reviewer was not clear why 1 MW was selected, and said component efficiencies were also not explained, therefore no comparison is included on the project goals or results/improvements.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer pointed out that successful test of vehicle safety systems, optimization of electrical systems and components to maximize efficiency, and DCFC charging, and 1,800 miles of vehicle testing have been concluded. Additionally, wireless charger development is progressing with some supply chain challenges.

Reviewer 2:

The reviewer said it is unfortunate that the charge site needs relocating since that represents a setback to the timeline. Also, it would be good to see how the truck sub system efficiencies are being tracked for progress, i.e., traction motor, steering etc. The reviewer said it is commendable the project will be compared to a kilowatt/hour earlier generation battery electric truck.

Reviewer 3:

The reviewer noted this project has suffered several setbacks—both with the vehicle and wireless charging components. Having said that, the team continues to press on towards the final goal. Real world verification of modeled systems is essential as our society moves towards battery electric vehicles (BEVs).

Reviewer 4:

The reviewer was unclear how this project impacts increasing BEV range other than the one objective to "add 170 miles of range" (to support a 400-mile total) with a 30-minute charge. The base BEV statistics need to be explained and a comparison chart would help clarify this projects goals and results.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer remarked the project team includes a balanced and complete team.

Reviewer 2:

The reviewer said that although somewhat behind due to problems and charge relocation, it sounded like the team is making progress and still plan to finish on time.

Reviewer 3:

The reviewer said a broad team of partners covering all relevant areas for a successful technology development and demonstration was initially assembled. Kenworth is the prime applicant and truck OEM, United Parcel Service as an end user fleet, WAVE as the wireless technology company and Utah State University who has been leading wireless technology research over the past decade. The two local utilities in Washington and Oregon state originally participated as demonstration locations; since demonstration is shifting to Utah, the team is working on onboarding new utility partner, which could cause a potential scheduling delay.

Reviewer 4:

The reviewer was unable to determine from this presentation how well the team has actually worked together. The reviewer wondered if some of the initial delays were caused by poor team coordination. There was insufficient detail given in the presentation to determine all of the causes for delay.

Question 4: Please comment on the 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:

Although not specifically addressed, the reviewer assumed the listing of challenges would represent areas of needed future research and development.

Reviewer 2:

The reviewer remarked the future work identified is in line with the original project plan. Having said that, this team has an uphill battle to complete everything in a timely fashion.

Reviewer 3:

The reviewer said the period of performance extension through June 30, 2024, will hopefully allow for 3 months of in-use demonstration to be completed by UPS drivers. Next milestones are a full-scale demonstration of megawatt wireless charger system off-vehicle and installing the system on vehicle and at two demonstration locations. The reviewer said motor/transmission challenges due to early prototype with demonstration location shifting from flat northwest route to a hilly Utah route could pose additional challenges to a successful in use demonstration.

Reviewer 4:

The reviewer said accomplishments identify several vehicle and charger systems that are not explained in this presentation. Perhaps more detail of what was accomplished with Safety, Fault handling, thermal, charging control, etc. can be summarized or may need further research to identify how these were improved.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer said electric Class 8 truck zero emission technology development and demonstration directly supports the objectives of the VTO Electrification subprogram.

Reviewer 2:

The reviewer believed this project is highly relevant to the DOE programs and hope that the learning of the wireless charger will be shared as soon as possible to help move that protocol forward for customers.

Reviewer 3:

The reviewer noted that extended range operation and wireless charging are both topics of interest for VTO. The reviewer wondered if this project should have actually been two separate projects.

Reviewer 4:

The reviewer remarked higher power is expected but this project still does not identify why 1MW was selected vs. others.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said no resource problems were identified by the project.

Reviewer 2:

The reviewer commented the participants satisfy the various categories required to accomplish a complete summary of the project.

Reviewer 3:

The reviewer said $8.6 million project with $5 million DOE share seems appropriate for a 5-year development and demonstration project of a new HD Class 8 truck propulsion system and charging technology.

Reviewer 4:

The reviewer remarked this is a very large project—maybe should have been split into two separate projects. The reviewer was not sure if more funding would have been helpful, but it might have.

Presentation Number: ELT264
Presentation Title: Demonstration of Utility Managed Smart Charging For Multiple Benefit Streams
Principal Investigator: Stephanie Leach (Exelon/Pepco Holdings, Inc.)

Presenter

Stephanie Leach, Exelon/Pepco Holdings, Inc.

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.

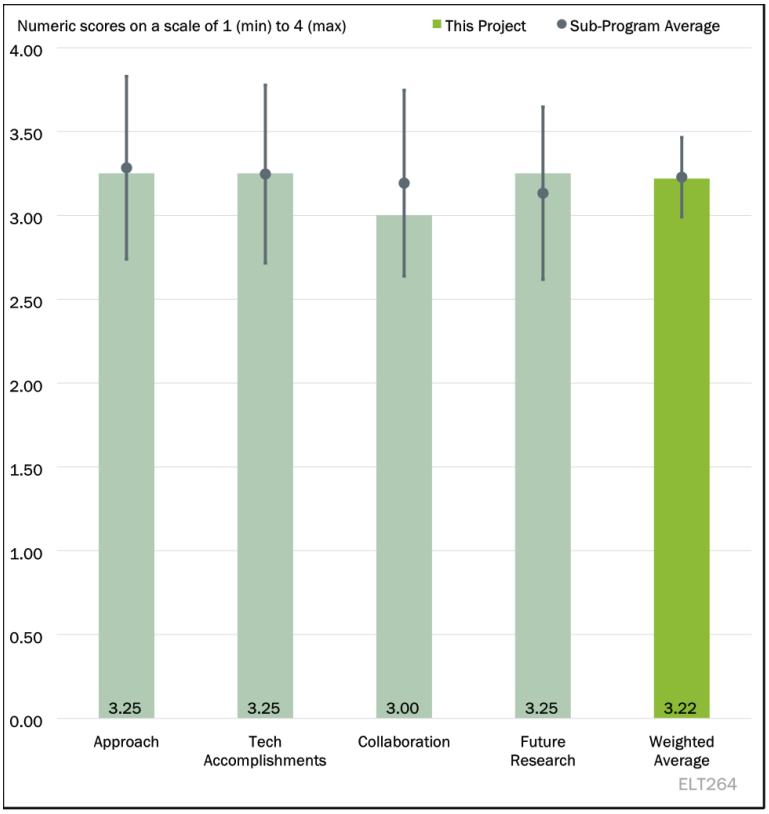

Figure 2-21 - Presentation Number: ELT264 Presentation Title: Demonstration of Utility Managed Smart Charging For Multiple Benefit Streams Principal Investigator: Stephanie Leach (Exelon/Pepco Holdings, Inc.)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer noted this is year three of a 4-year project. The 2023 "Barriers and Technical Targets" are completely different than in 2022, so the reviewer was unsure if the project focus had changed with DOE approval. The contract end date is noted on Slide 2 as December 2024, but Slide 4 mentions work being completed in March 2025. The approach seems to be logical and the presentation style (Slide 5; colored boxes, lines linking Objectives to Expected Outcomes/Milestones) is simple and effective.

Reviewer 2:

The reviewer said the project appears to focus on the mechanics of a smart charge management (SCM) prototype capability in the context of a low EV penetration environment where there is sufficient grid capacity to meet EV charging demand. The PI's response to reviewer questions regarding quantification of EV consumer costs indicates that there have been insufficient considerations of the metrics for trade-offs to be made when charging demand saturates the capabilities of the grid and some charging needs go unmet. The high penetration scenario mentioned will likely introduce saturation conditions which deserve more robust metrics to unlock the value of this project.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer remarked the project schedule shows that significant progress has been made to implement the project plan.

Reviewer 2:

The reviewer said progress looks to be significant among the different efforts and partners. The details on Slides 6–7 are clear using the same presentation method as the approach summary. based on the Slide 4 schedule it seems like the project is on track. However, having all of the 2023 milestones for December 31, 2023, seemed odd to the reviewer given DOE may require at least one milestone per quarter. The reviewer observed each milestone may be for different team members' roles, but having multiple milestones along the way for each would make sense for the project team and DOE to more effectively manage progress to make sure no surprises arise. The reviewer notes the progress on all sub-efforts (smart charge management [SCM] demo, Agent-based Transportation Energy Analysis Model [ATEAM] modelling, ATEAM Transmission Distribution [ATD] modeling).

Question 3: Please comment on 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?

Reviewer 1:

The reviewer remarked the teaming between Exelon (Baltimore Gas and Electric [BGE] and PECO) with Argonne National Laboratory (ANL), Weave Grid (telematics), and EVSE/charging network service providers (Shell Recharge Solutions and EVmatch) seems to be a logical and complementary combination of expertise. Project roles are clear given the organization's expertise and functions. The details by effort listing organizations that are supporting is very clear. The project seems to be well-coordinated with defined tasking and information handoffs between the sub-efforts.

Reviewer 2:

The reviewer said this project would benefit by increasing the collaboration between the ANL modeling team and the project lead so that the full implications of grid resource constraints can be addressed.

Question 4: Please comment on the 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 proposed future work is to accomplish the remaining project scope, so it is logical.

Reviewer 2:

The reviewer said future work makes sense to complete the grid mechanics focus of the pilot.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer remarked the project is highly relevant to the Electrification subprogram objectives to develop and demonstrate smart charge management (SCM) capabilities that can help mitigate the impact of EV charging on the electric grid.

Reviewer 2:

The reviewer commented very relevant project to DOE goals and the utility industry's needs to develop technology/behavioral approaches to manage power demand for grid health. The project is

developing/conducting a SCM demonstration across different customer types (residential, commercial and public) to develop optimal managed charging approaches for the grid. The project is also evaluating the impact of wide-scale EV charging on utility distribution operations and evaluate the ability to control EV charging load based on grid conditions.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented DOE funding role in the project seems to be adequate. The cost shared funds are likely to fund partner roles since it is expected Exelon's investment was per the Maryland Public Service Commission approved budget. If so, this all makes sense.

Reviewer 2:

The reviewer remarked the accomplishment of project milestones to date suggests that there are sufficient resources to achieve all the project milestones.

Presentation Number: ELT265
Presentation Title: A Secure and Resilient Interoperable SCM Control System Architecture for Electric Vehicles-At-Scale
Principal Investigator: Duncan Woodbury (Dream Team LLC)

Presenter

Duncan Woodbury, Dream Team LLC

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.

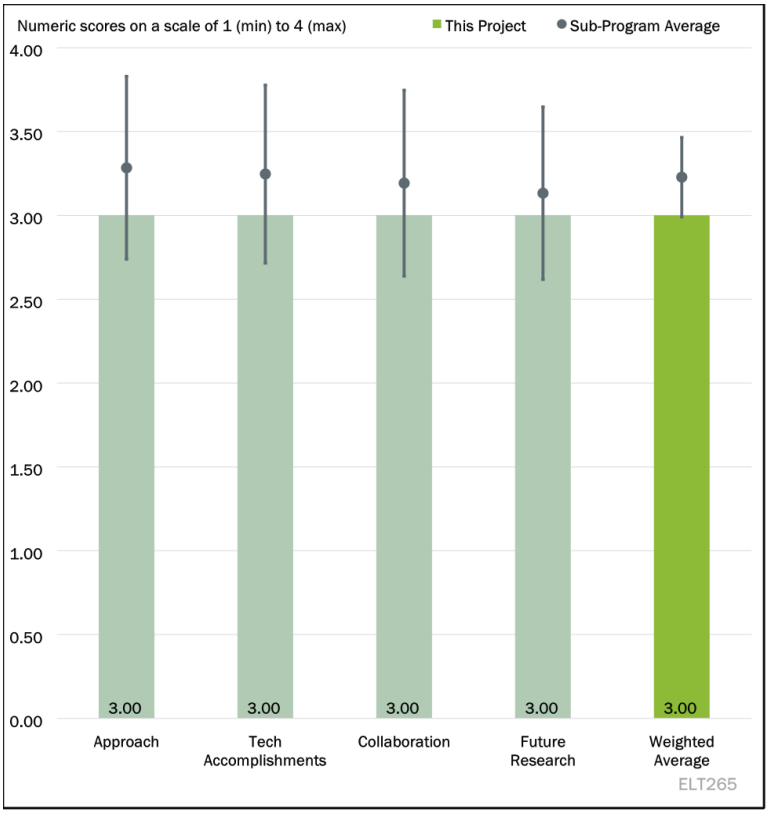

Figure 2-22 - Presentation Number: ELT265 Presentation Title: A Secure and Resilient Interoperable SCM Control System Architecture for Electric Vehicles-At-Scale Principal Investigator: Duncan Woodbury (Dream Team LLC)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer detailed EVs-at-RISC is targeting an open-source, open standards based SCM system for distribution networks with support for interoperable, secure management and grid integration of EVs, EVSE, and distributed energy resource (DER) EVs-at-RISC will not create new standards nor protocols, but instead is developing an approach to map existing standards back to International Electric Code (IEC) 61850/common information model (CIM). The system is professed to be applicable for vehicle grid integration (VGI), as well as vehicle to grid (V2G). This project has undertaken an innovative strategy to achieve its aggressive objectives. It includes implementation of a universal grid edge protocol through the extension of open field message bus (OpenFMB); hosting distributed public key infrastructure policy tools, and deployment in a zero-trust middleware layer; and leveraging external “oracles" to provide control triggers for grid automation. Overall, the reviewer remarked this is a very innovative and aggressive approach which, if successful, would significantly advance and potentially enable widespread implementation of flexible utility SCM systems across a wide variety of utility stakeholders, system architectures, and technologies.

Reviewer 2:

The reviewer said the approach is yet to be tested on large scale and with smart grid interface.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer said the project has demonstrated significant progress, technical accomplishments, and advances in technology readiness levels over the last year. Essentially all major tasks and achievement of milestones (including year 1 go/no-go) are successfully completed or on schedule. This includes: (1) Successful multi-protocol to OpenFMB adaptation validated for data normalization to IEC 61850/CIM allowing multiple vendors to be used; (2) Multiple site integrations within the EVs-at-RISC platform, and; (3) A multiple-site SCM demo over distributed networks with important use cases demonstrating achievement of key metrics therein.

Reviewer 2:

The reviewer said the project is still in the development stage and needs to consider a large-scale smart grid utility interface and a standard protocol similar to that of EPRI.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer suggested the project coordinate with EPRI for their experience in smart grid V2G.

Reviewer 2:

The reviewer commented that Liberas has assembled a strong, diverse team including a utility, national laboratories, transportation development center, security firms, university, and a non-profit. There are no apparent gaps in the team structure as all elements of RDD&D, including extensive demo sites and cybersecurity, are covered.

Question 4: Please comment on the 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 needs to expand the test cases and consider a common protocol among the utility providers.

Reviewer 2:

The reviewer remarked the project R&D is largely complete, and the effort is preparing to enter wide-scale demonstration and will deploy its platform across live distributed EVSE/DER networks. It will demonstrate production use of the platform for smart charging and distribution system operator/independent system operator grid services. The project is also focusing on reducing the "distance to integrate" and becoming truly seamless. This is excellent.

However, the project presentation mentions significant challenges therein including unique integration challenges, and regulatory and cybersecurity compliance barriers. Further elaboration of these areas would be beneficial. For example, the reviewer cited are there any potential showstoppers and how exactly does the variety and diversity of sites present unique integration challenges? Finally, are there any other unique business or commercialization barriers to widespread commercialization of the EVs-at-RISC platform? If so, how will the system specifically demonstrate enough value to overcome these barriers and what are the metrics for success?

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer said the project needs to have a common protocol among the grid companies.

Reviewer 2:

The reviewer pointed out that without adaptable, commercially viable SCM systems, utilities will have to invest much more heavily in infrastructure build-out and capability upgrades to meet electricity demand from EVs. This will substantially increase costs, ultimately being passed onto the consumer, and hinder the progression of widescale EV implementation and vehicle-grid integration.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said resources seem to be okay.

Reviewer 2:

The reviewer said the resources seems sufficient and appropriate to successfully conduct the project and achieve project milestones. The current spend rate is on track corresponding to project schedule and progress, and the project has a strong cost-share of approximately 32%.

Presentation Number: ELT274
Presentation Title: eMosaic, Electrification Mosaic Platform for Grid-Informed Smart Charging Management
Principal Investigator: James Stoupis (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.

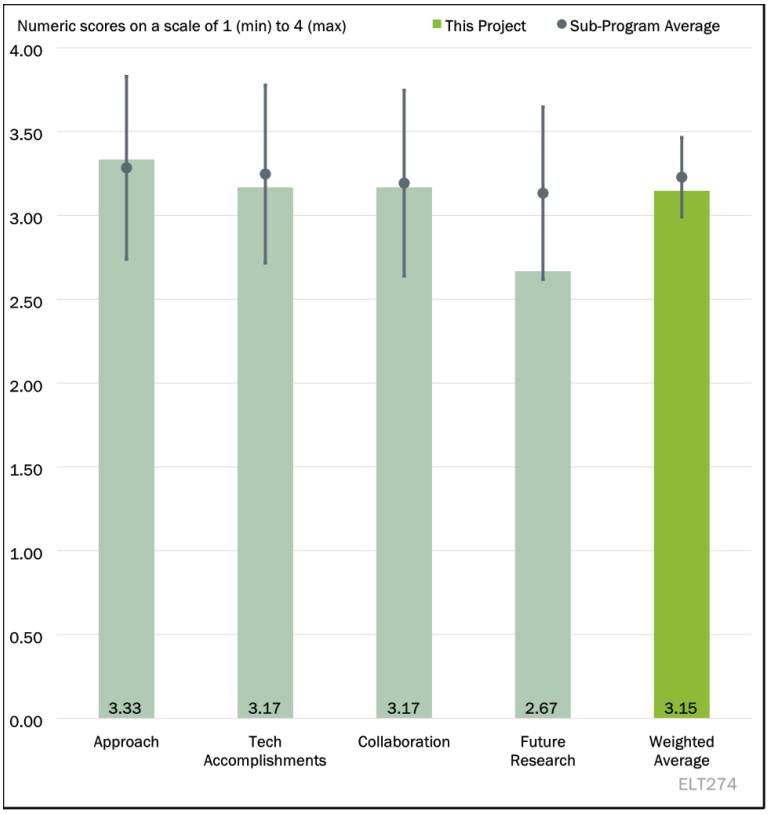

Figure 2-23 - Presentation Number: ELT274 Presentation Title: eMosaic, Electrification Mosaic Platform for Grid-Informed Smart Charging Management Principal Investigator: James Stoupis (ABB)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer noted that a few minor delays on subtasks have not affected the overall project schedule. With early phases complete, the project is ready for real-world demonstrations.

Reviewer 2:

The reviewer said the project's scope is relevant and has widespread applications.

Reviewer 3:

The reviewer noted that as presented, the approach appears sound and the project outlines a detailed task structure to meet its objectives. The reviewer very much appreciates the specific identification of evaluation criteria for each of the four demonstration cases. The barriers mention the desirability of a high level of interoperability. It is good that several tasks (e.g., 2.2.1, 3.1.3, and 3.1.5) specifically relate to interoperability. The reviewer assumes these "interoperability" tasks include the relevance of codes and standards and will consider their evolution moving forward and potential resulting impacts? Overall, it is important to clearly define project "measures of success." The PI indicated the following as "measures of success:" test procedures; getting to the point through testing in the field and addressing commercialization barriers—specifically grid-edge challenges such as sending data to the cloud with cybersecurity and the complications of open automated demand response (OpenADR). These seem important and broadly comprehensive and appear appropriate to emphasize as measures of success.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer remarked the demonstrations plans that have been developed cover a good range of use cases and should result in valuable findings when executed.

Reviewer 2:

The reviewer found that progress is on track.

Reviewer 3:

The reviewer said a solid and steady listing of technical accomplishments has been indicated through the task "tree" and milestone progress table. Tasks and milestones have been modestly delayed over the last year (approximately 6-month lag), but, in general, are steadily progressing. Budget period 2 go/no-go has been successfully completed. For demonstration cases 1 (dynamic pricing) and 2 (bus charge planning) it may be beneficial to consider additional evaluation elements. This could include socio-economic demographics with regards to dynamic pricing; and/or battery degradation and the impact on service personnel requirements as secondary issues for bus charge planning.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer said collaboration is on track.

Reviewer 2:

The reviewer noted the team is lean but sufficiently broad and diverse to meet project objectives and requirements. Team partners appear to be addressing and conducting appropriate roles and responsibilities. While it may be beneficial to add additional project participants, it doesn't really appear to be absolutely necessary.

Reviewer 3:

The reviewer said key team members seem to be working together well to execute plan. As noted by previous commenters, the team could be strengthened by more participation from EV network service providers (NSP). Most end users/sites host will not want to directly work with the utility but will want their NSP to do that.

Question 4: Please comment on the 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 project is currently transitioning into a demonstration phase, which should help answer and validate many of the outstanding research questions. However, more specificity could have been added on future (beyond the project end) research.

Reviewer 2:

The reviewer said the project needs to consider large-scale data mining and varied test conditions.

Reviewer 3:

The reviewer noted that the team provided a solid listing of tasks for budget periods 3–4. The remaining challenges and barriers largely identify technical challenges and barriers. It would be beneficial to continue further strong consideration of the potential commercialization challenges such as interoperability, codes and standards, cybersecurity implications, and regulatory/policy evolutions and impacts. Plans to work through the

Utah State University network of Advancing Sustainability through Powered Infrastructure for Roadway Electrification (ASPIRE) Center parties for feedback is good and should be strongly pursued.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer said good testing of multiple smart charging use cases.

Reviewer 2:

The reviewer remarked as the electrification portfolio grows, the need for data management becomes critical.

Reviewer 3:

The reviewer agreed yes, the project is relevant. Without the availability of effective, commercially viable SCM systems, utilities will have to invest heavily in infrastructure and capacity upgrades to meet the electricity demand of EVs.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said the project seems to have been successful so far and is on schedule to complete its demonstration testing.

Reviewer 2:

The reviewer said resources are on track.

Reviewer 3:

The reviewer remarked the resources appear sufficient to meet the objectives and milestones as detailed in the project. The cost share (20%) is minimal, but adequate.

Presentation Number: ELT278
Presentation Title: EVs@Scale Lab Consortium
Principal Investigator: Andrew Meintz (National Renewable Energy Laboratory)

Presenter

Andrew Meintz, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers 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.

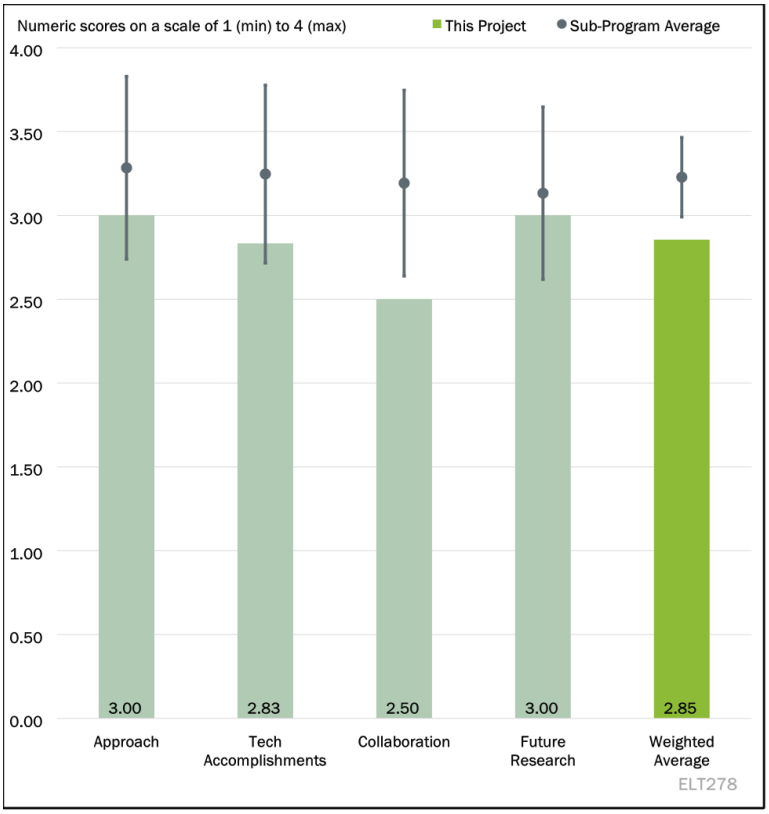

Figure 2-24 - Presentation Number: ELT278 Presentation Title: EVs@Scale Lab Consortium Principal Investigator: Andrew Meintz (National Renewable Energy Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer said the consortium approach will enable the team to meet their objectives of develop plug-and-play solutions allowing a charging site to organically grow with additional chargers and DER through predefined compatibility with standards that will ensure interoperability and reduce upfront engineering expense. The team structure and participants are appropriate. This project will analyze and demonstrate Smart Charge Management and Vehicle Grid Integration approaches to reduce grid impacts from EVs@Scale, as a result of the charging needs of the on-road electrified fleet.

Reviewer 2:

The reviewer noted this is a difficult project to evaluate because it appears to me that each pillar could have been its own project since they appear to have only superficial if any inter-dependence. That said, the work within each pillar is generally well organized although it is not clear to me how this will translate into actual large-scale use. No timeline is specified and several of the outcomes are vague.

Reviewer 3:

The reviewer commented that the project is "way too large" in scale. The project should have been broken down into five separate projects according to the five pillars: Vehicle grid integration & smart charge management; high-power charging; wireless power transfer; cyber-physical security; and codes & standards. While there may be interaction or integration between the pillars, for the most part, they are minor and

standalone (especially, wireless power transfer). There is no need to add another layer of management and oversight.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that it is extremely difficult to link the objectives and outcomes to the milestones because the project plan is not given, the objectives and outcomes are very generally stated and insufficiently specific, and not all the milestones are given. Also, it is not possible to determine if a particular milestone was changed to avoid reporting a delay in progress. For example, for the VGI/SCM, the objectives were stated too generally and only three outcomes were identified: identify limitations and gaps in VGI/SCM; develop/demonstrate VGI approaches; and determine VGI and SCM benefits. These outcomes were not broken down into milestones and the milestones given in the presentation do not match/correspond to the outcomes given.

Reviewer 2:

The reviewer said all five pillars of the project have accomplishments. The SCM and VGI pillar has accomplished trip data acquisition and preprocessing. EV adoption modeling synthetic travel itineraries were validated against 2017 NHTSA vehicle trip distributions. For EV charging simulation, NREL research was used to simulate EV charging behaviors, energy demands, and infrastructure requirements. Generate location-specific load profiles is on-going work to assign charging demands to specific locations (e.g., land parcels) by location type. The High-Power Charging Pillar accomplishment was a 1000V, 175 kW Dual-Active-Bridge based charger was built and tested. The reviewer noted that for the Wireless Power Transfer Pillar, the team developed four devolved pre-cast concrete blocks, assembled four primary side power electronic units, which were tested and ready to be shipped. Also, two vehicle side units assembled and ready to be shipped. The Cyber-Physical Security Pillar developed the opportunity to map tools and capabilities to EVSE security functions and needs. The team also constructed a dynamic database for engaging with industry as well as ingested initial data from surveys. The Codes & Standards Pillar identified issues as well as standards, codes, and regulations that exist or are in development to address the issues. The team identified the gaps and recommended development of new or revised standards as well conformance and training programs, where needed.

Reviewer 3:

The reviewer said each pillar appears to have some accomplishments to share but again, given the lack of specificity on timelines or goals, it is difficult to know if the project is on plan.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer said coordination and collaboration across the national laboratories is acceptable, but the presentation did not list the private sector companies participating in this project. It is critical to know who is actively participating and whether they are providing significant input on this project. The utilities, EVSE and EV manufacturers, charge network operators (CNOs), standards development organizations (SDOs), other government agencies and infrastructure organizations, at least the major players if not all of them, have to be named for the reviewer to give credit for this question or criterion of evaluation. The reviewer suggests that people in the background, behind the scenes, who are supporting the project are neither acknowledged nor given credit for their contributions.

Reviewer 2:

The reviewer commented the project has a Stakeholder Advisory Group that includes utilities, EVSE & vehicle OEMs, CNOs, and SDOs. They are involved with government infrastructure direct interaction for each pillar projects. The team holds webinars/project discussions and semi-annual high-level meetings with all parties.

Reviewer 3:

The reviewer remarked most pillars could benefit from deeper industry collaboration to help shape the project and to help ensure that this work sees beneficial use. Only a few pillars mention any direct industry collaborators.

Question 4: Please comment on the 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 supports the overall goals of each pillar with several demonstration planned. The reviewer hopes the demonstrations in particular will result in interest and input from a broad group of industry participants.

Reviewer 2:

The reviewer found that proposed future research in the pillars of vehicle-grid integration & smart charging management, wireless power transfer, and codes & standards are satisfactory. However, proposed future research in the pillars of high-power charging and cyber security is unsatisfactory. For high power charging, the future proposed research does not match the identified remaining challenges and barriers. For cyber security, no future proposed research is addressing inconsistent implementation and utilization of latest security methods, recovery from adverse cyber events, training for the EV cybersecurity work force, lack of hardware to identify physical or cyber threats at charging stations, and transition to post-quantum computing cryptology.

Reviewer 3:

The reviewer remarked all pillars have work to do. The Smart Charge Management and Vehicle Grid Integration Pillars are conducting charging analyses on medium- and heavy-duty vehicles as well as co-simulation uncontrolled/controlled grid impact analysis. The High-Power Charging Pillar will perform evaluation and comparison of various site energy management system (SEMS) control algorithms with ESS and improving grid integration. The team is developing a universal power electronics regulator (UPER) (1000V class charger) with Spec-II module integration and evaluation with DC Hub—Develop impactful NextGen Profile analysis that can guide performance standards and inform industry from continued test execution and data gathering. The Wireless Power Transfer Pillar will conduct a 200 kW dynamic wireless power transfer (DWPT) demonstration in the field, and conduct comprehensive review of 200 kW DWPT system and identify gaps to deployment in real world cybersecurity. The Cyber-Physical Security Pillar will increase focus on electrified vehicles and charging infrastructure. The team will also focus on demonstrating high-power DC charging Infrastructure cyber-physical security mitigation solutions. Cyber Tools and Solutions for EVSE will open interface to industry solution providers. The Codes & Standards Pillar will finalize the megawatt charging system (MCS) coupler thermal-mechanical testing results report.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer said the EV and charging infrastructure industries are accelerating their activities. This speed requires quick action from the DOE and national laboratories to ensure our efforts remain relevant.

Reviewer 2:

The reviewer remarked the project supports the overall electrification objectives, albeit in ways that are difficult to measure or quantify.

Reviewer 3:

The reviewer would drop the wireless power transfer pillar. This concept is premature and irrelevant to contemporary needs.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said the project team does not identify any constraints that keep them from meeting their stated objectives.

Reviewer 2:

The reviewer remarked there appears to be sufficient funding for the next 4 years.

Reviewer 3:

The reviewer said this project is extremely similar to another project (the "GEMINI" project). The only difference is in the type of travel data used—agent-based or conventional travel profile.

Presentation Number: ELT282
Presentation Title: Technology & Design Innovations to Maximize the Reduction Effect on DCFC Unit Cost Economics (Max-REDUCE)
Principal Investigator: Robert Keefover (Borg Warner)

Presenter

Robert Keefover, Borg Warner

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.

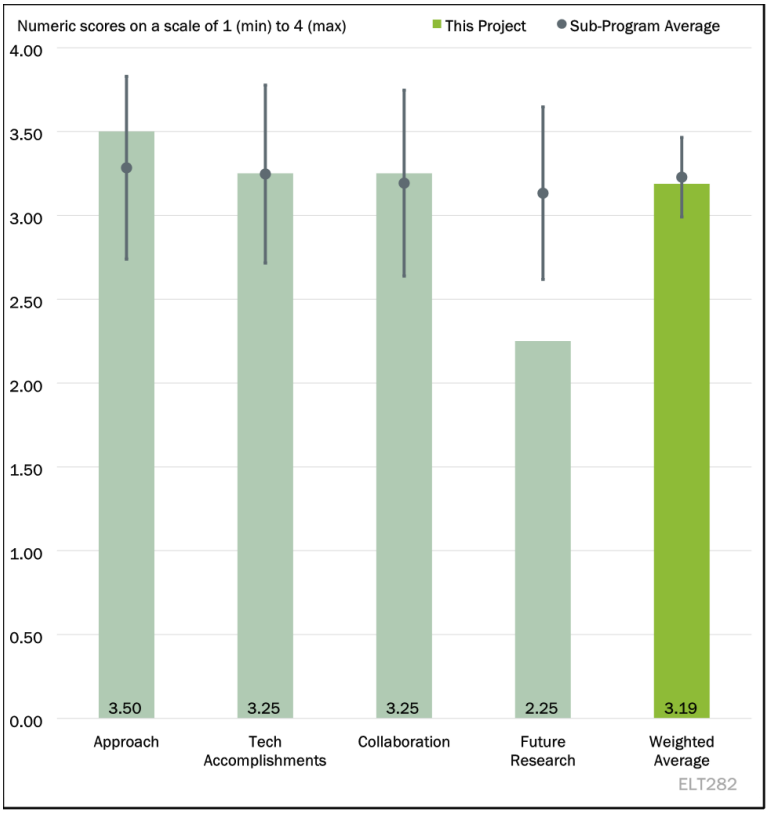

Figure 2-25 - Presentation Number: ELT282 Presentation Title: Technology & Design Innovations to Maximize the Reduction Effect on DCFC Unit Cost Economics (Max-REDUCE) Principal Investigator: Robert Keefover (Borg Warner)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer remarked the scope of the project addresses the technical barriers by focusing on power density, efficiency, interoperability, and reliability.

Reviewer 2:

The reviewer said the approach to using silicon carbide (SiC) power device rather than conventional Si-based power devices defies the goal for achieving an optimized cost. The Approach should consider a least maximum standardized maximum power up to 500 kW to enable achieving the goal of fast charging experience.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer remarked accomplishments clearly show the charger architecture functionality through modeling and simulation. Additionally, a 5 kW proto-type unit is ready for testing.

Reviewer 2:

The reviewer said the hardware evaluation is not yet demonstrated with the intended max power design.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer said a good collaborative team has been assembled to enable a successful project.

Reviewer 2:

The reviewer commented industry input seems to be less evident especially taking into consideration the exiting charging infrastructure and industry standards SAE J 1772.

Question 4: Please comment on the 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 plan for the goal to achieve max power design and testing is not evident.

Reviewer 2:

The reviewer remarked t is unclear if the future scope is a significant change from the current project scope. The Relevance slide indicates 150 kW "….modular, single stage …DCFC… w/ unit cost reduction of more than 20%; and minimum 97% efficiency." In the summary slides, the table indicates the baseline is a "bi-directional" charger. A "uni-directional" charger is indicated as the intermediate step with significantly lower part count, and the end goal (highest efficiency, highest power density, and lowest cost) is shown as "new bi-directional design." Is the future project scope focused on developing a 60 kW bi-directional charging or a 150 kW unidirectional DCFC? The reviewer said this definition of project design target should be clarified at the beginning of the presentation.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer said this project supports the objective by reducing costs and improving efficiency of EV charging infrastructure.

Reviewer 2:

The reviewer mentioned they had no comment but noted the approach and next steps should be re-evaluated to address stated project barriers.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said the funding is sufficient for the development and field demonstration of multiple 150 kW DCFC units in use with a small fleet of BEVs.

Presentation Number: ELT283
Presentation Title: A Solid State Technology Enabled Compact, Modular Design to Reduce DC Fast Charging Cost and Footprint
Principal Investigator: Vijay Bhavaraju (Eaton)

Presenter

Vijay Bhavaraju, Eaton

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.

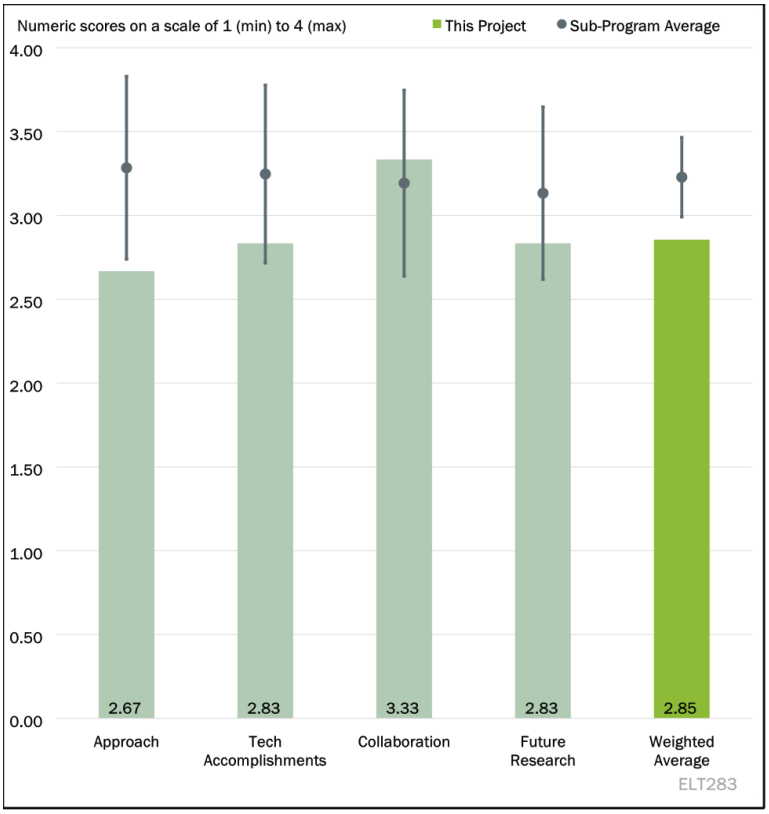

Figure 2-26 - Presentation Number: ELT283 Presentation Title: A Solid State Technology Enabled Compact, Modular Design to Reduce DC Fast Charging Cost and Footprint Principal Investigator: Vijay Bhavaraju (Eaton)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer remarked this appears to be an excellent project addressing the needs of early EV adopters and infrastructure cost.

Reviewer 2:

The reviewer commented the project addresses details for reducing the footprint size of medium voltage connected, megawatt charging systems. No clear details were provided on how the project deliverables will decrease costs or ensure interoperability with megawatt charging capable EVs.

Reviewer 3:

The reviewer commented that while this is a technically deep and comprehensive project, the presentation does not include information on the barriers of the footprint, and the information on cost-reduction is inadequate. The presentation needs a short introduction on the baseline technology and how this project is going to improve the situation. There was not discussion of footprint reduction or key problems solved with respect to interoperability. Finally, the reviewer added that their "fair" score could be considerably improved with added information.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer said the material seems to clearly articulate all the achievements and well documents project progress.

Reviewer 2:

The reviewer said the overall progress in design and construction appears good, but the impact on the barriers of size, cost, etc. is not well covered. The recording contained appropriate information on some hindrances to progress that was helpful and understood.

Reviewer 3:

The reviewer noted the project has accomplished several design and modeling tasks as well as initiated the underserved community requirements process. The project results do not include any cost estimates for the completed designs or comparisons to the cost for a comparable state-of-the-art medium voltage-connected MW charger. The project does not include any results or accomplishments to ensure interoperability with MW charging capable vehicles.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer commented there seems to be a healthy share of responsibilities amongst project partners.

Reviewer 2:

The reviewer said the tasks by the contributing team members are tabulated and adequately described. The recorded presentation was beneficial in this category. It would be useful to see the approximate funding to each partner. The team's effort to understand and support benefits in underserved/impacted communities is articulated clearly, and commendable. The reviewer said the workshop mentioned seems like a good idea.

Reviewer 3:

The reviewer remarked the project includes project partners with modeling expertise and underserved community outreach experience. Consider adding project partners for improved capabilities to successfully test and demonstrate the medium voltage connected megawatt charging infrastructure.

Question 4: Please comment on the 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 remaining challenges are well articulated.

Reviewer 2:

The reviewer said the requirements and challenges to complete the device and install it are presented clearly. The future work should include, however, an analysis of the impact on the barriers of cost and footprint, etc.

Reviewer 3:

The reviewer noted the project's proposed future research includes design and modeling of advanced power electronics topologies and controls including DER. Consider testing and demonstrating the megawatt charging system in the current project to gain lessons learned, prior to further modeling and design of other advanced topologies.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer noted the project's focuses on electrification/mobility systems.

Reviewer 2:

The reviewer remarked improvements in charging equipment and infrastructure are certainly relevant to VTO's overall mission to enable progress toward low-carbon mobility. Cost reduction and minimizing intrusion on communities are good objectives.

Reviewer 3:

The reviewer commented reduced costs for medium voltage connected megawatt charging systems directly supports the objectives to advance electrified transportation charging infrastructure system integration.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said the project seems to be adequately funded.

Reviewer 2:

The reviewer suggested showing distribution of resources across team members.

Reviewer 3:

The reviewer said that for this 3-year project, the project claims 57% completed after 13 months (May 2022 to June 2023). This indicates the project is anticipated to be underbudget by the completion of the project milestones.

Presentation Number: ELT284
Presentation Title: Ultra-low Cost, All-SiC Modular Power Converters for DC Fast Charging Equipment Connected Directly to Medium Voltage Distribution System
Principal Investigator: Srdjan Lukic (North Carolina State University)

Presenter

Srdjan Lukic, North Carolina State University

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.

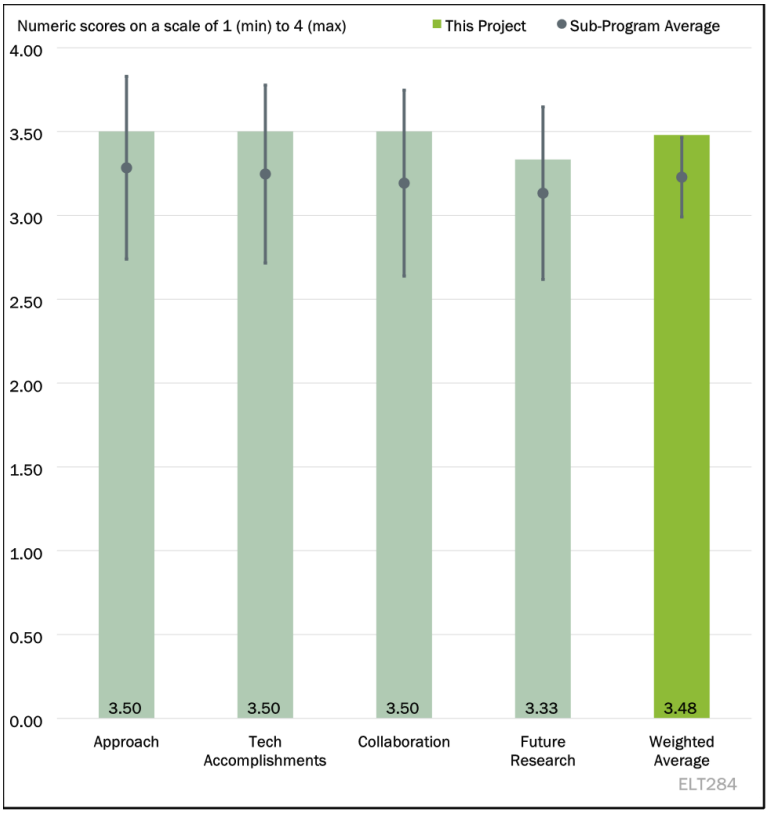

Figure 2-27 - Presentation Number: ELT284 Presentation Title: Ultra-low Cost, All-SiC Modular Power Converters for DC Fast Charging Equipment Connected Directly to Medium Voltage Distribution System Principal Investigator: Srdjan Lukic (North Carolina State University)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer said the project is well designed to include technical as well as financial objectives. While Multi-port DAB is complex to control, the cost of the system should be reduced with an overall decrease in hardware components. When DAB circulating currents were discovered to be causing a loss of efficiency, the team set out to redesign the magnetics to get that efficiency back. The reviewer stated being happy to see that this project includes as a part of its scope a cost of ownership analysis.

Reviewer 2:

The approach of this project is tailored to reduce cost of XFC by resorting to the single-stage power conversion, resulting in expected 50% cost reduction compared to the baseline XFC engineered through project ELT238. Use of the SiC devices is targeted to lower the footprint of the magnetic circuit used in an XFC system, which matches with engineering practices, presently prevalent in the power electronic field. The reviewer noted the cost reduction realization will be achieved by minimizing the cost of protection mechanism used with the underlined XFC system.

Reviewer 3:

The reviewer noted the project has very strong, clear objectives and deliverables covering technical, cost, and business aspects of SST technology development and commercialization. Regarding objectives, this reviewer reported reducing the cost of SST-based EVSE by at least 50% compared to baseline system; improving reliability; and identifying best technology insertion points by analyzing the TCO of SST-based EVSE. Concerning deliverables, the reviewer noted that all SiC-based EVSEs are operational in the field and highlighted TCO analysis.

The reviewer said SST-based systems will have higher efficiency (SST expected efficiency greater than 97%) and smaller footprint compared to conventional baseline systems. The overall cost reduction approach is excellent. There is a very heavy emphasis upon cost reduction through analysis, establishing cost of ownership targets, and initial prototyping very early in the project (Fiscal Year 2023). The reviewer said the project incorporates a number of innovative cost reduction strategies including: (1) design for manufacturing / utilizing same device / cooling construction; minimizing the cost of DC protection and; (2) minimizing the cost of DC nodes through galvanic isolation from the SST. The total cost of TCO methodology is comprehensive including not only upfront equipment costs, but also maintenance and operations costs. Model development scenarios are being explored/examined including regional variances and recommendations for best use case scenarios. Furthermore, it is good to see extensive industry interviews (manufacturers, installers, owner/operators, and fleet managers) being included in the project. The project has incorporated risk mitigation strategies of which Danfoss has been instrumental. This includes a technology transfer plan with multiple pathways to market and standards testing to be conducted as part of testing in budget period 3.

Finally, the project also incorporates proactive workforce development.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer said the project has demonstrated very strong technical progress in the first year, as well as emphasis upon cost reduction and market transition strategies. A comprehensive topology tradeoff was conducted prior to settling upon the pseudo flying capacitor approach which is relatively low risk. Technical progress includes: systems specifications defined and topology selected; initial transformer prototyping complete; initial simulations meeting performance and efficiency targets; and the project is on track to quantify the value proposition and determine the best insertion points for technology and to quantify the benefit over the state of the art.

Reviewer 2:

The reviewer said it is early in the project, but accomplishments have been good as compared to the plan. The project fell behind at the beginning because the needed cost analysis and cost of ownership targets were late to engage but it looks like it is running to plan now (with a small, no-cost extension).

Reviewer 3:

The reviewer said the timeline of the project is targeted for high level activities starting from development followed by optimization which leads to system integration and development in last budget period during 2025–2026 timeframe. Each of these high-level tasks have many relevant sub-tasks outlined in the project report. The reviewer cited system specifications are developed and included in the project report. Adopted system topology illustrated in the project report. Outcome of topology takeoff study summarized in a table and included in the project report. Pseudo flying capacitor-based topology selected for the XFC power stage. Multiport DAB and its benefits described. Overall efficiency of the proposed XFC assessed and efficiency plot as function of power included in the project report. Homemade transformer for SST fabricated and picture

included in the project report. Methodology outlined for the TCO and tabulated data included in the project report. Cost reduction strategy resorts to elimination of switch gear and outlined and illustrated in the project report. The project has a workforce development plan, which is desirable and appropriate as industry needs technical experts who could become instrumental in EV adoption. The technology transfer plan outlined in the project report including PI aspirations to launch a start-up company.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer noted a good team of partners and contributions, and partners appear to play to each of their strengths. Great to see Workforce Development as a part of this plan. The reviewer hopes it pays dividends many times over.

Reviewer 2:

The reviewer remarked strong collaboration exists in execution of project activities and multiple entities are involved in the North Carolina State University-led project and the project team includes many industries.

Reviewer 3:

The reviewer commented the project team is lean and appears to be well rounded and appropriate. The team covers all relevant aspects including R&D, cost analysis, demonstration, and business/commercialization. No readily apparent gaps are noted in the team structure.

Question 4: Please comment on the 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 well-planned with tasks and timing communicated. When executed to that plan the project will demonstrate the technologies and cost effectiveness of those technologies.

Reviewer 2:

The reviewer remarked remaining challenges and barriers have been comprehensively identified, including those that are technical/design, cost/business, and project related in nature. Out-year tasks (including team roles and responsibilities) are presented which seem very appropriate. It is important to continue to address market/commercialization barriers (such as codes and standards, and regulatory/policy) regarding SST-based systems and whether utilities/PUCs will allow their incorporation. The PI has indicated that more demonstration projects will help reduce barriers and improve customer acceptance. It may be beneficial to continue to brainstorm further solution pathways regarding market/commercialization barriers.

Reviewer 3:

The reviewer commented the project report outlines future research, which is relevant and appropriate. Multiport DAB reduces cost, which is good. However, risks of DC current offset and possibility of magnetic circuit saturation need to be included as one of the tasks in the project activities. Otherwise, there is a possibility that this important aspect may remain unexplored, resulting in the possibility of an outcome that may be far from commercialization.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer pointed out that medium and HD EVs will require very high-power charging (up to and exceeding 1 MW). To provide the necessary power at a reasonable cost, direct connection to medium voltage

(MV) will likely be needed. New approaches to increase access, ease installation, and drive down infrastructure costs will be needed. The development and successful commercialization of SSTs will be instrumental to this effort.

Reviewer 2:

The reviewer noted how a cost-reduced (50%), modular, medium-voltage grid connected, fast charging system, if successful, has the potential to boost the uptake of EV charging availability throughout the United States.

Reviewer 3:

The reviewer said this project is relevant to VTO's electrification sub-program and will accelerate adoption of EVs by availability of XFC to HD and light-duty vehicles, and utilities will feel comfortable in allowing XFC interface with MV grid.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said resources are sufficient and having a partner like Danfoss, which brings commercial considerations to technical solutions, is probably helping in timely and cost-effective decision making on this project.

Reviewer 2:

The reviewer commented the project has necessary resources and research funds.

Reviewer 3:

The reviewer said the project appears sufficiently funded and exhibits 27% cost share, which is good.

Presentation Number: ELT285
Presentation Title: Development and Demonstration of Zero-Emission Technologies for Commercial Fleets (Supertruck 3)
Principal Investigator: Maarten Meijer (PACCAR)

Presenter

Maarten Meijer, PACCAR

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.

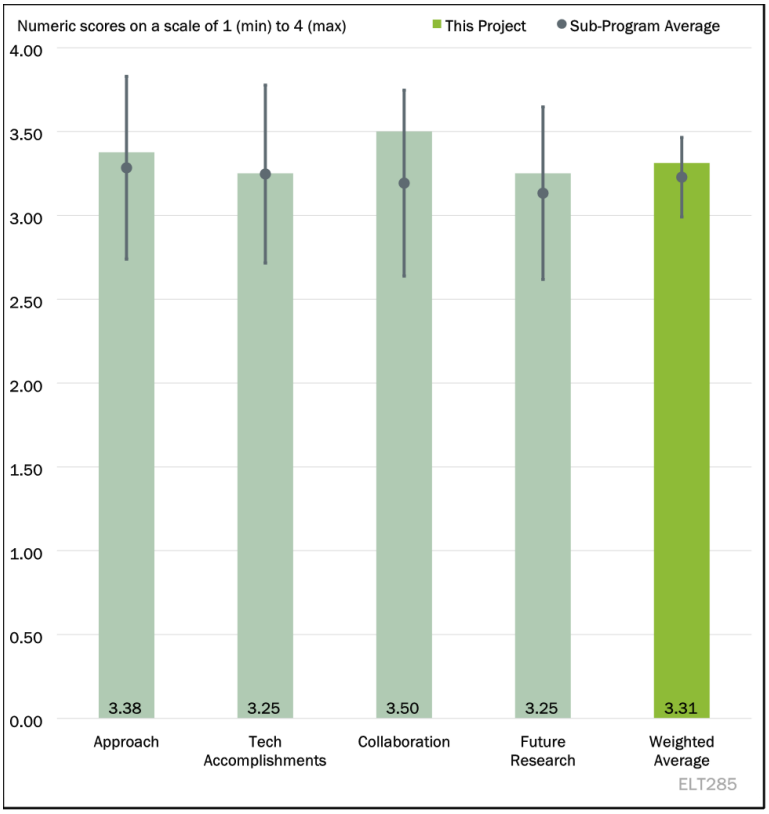

Figure 2-28 - Presentation Number: ELT285 Presentation Title: Development and Demonstration of Zero-Emission Technologies for Commercial Fleets (Supertruck 3) Principal Investigator: Maarten Meijer (PACCAR)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer remarked PACCAR has a project plan that is well considered and will push our current experience of technology.

Reviewer 2:

The reviewer said the barriers were well explained with technology areas being well explained and categorized (Vehicle/Powertrain/Infrastructure). Given this being the early phase of this project and complexity of a zero-emissions transport system (changing from internal combustion engine (ICE) to BEV in commercial fleets), as well as the carbon emissions and cost of ownership targets, development and demonstration, and finally breadth of team involved (fleet partners, research, charging expertise needed, etc.), the project appears well defined. It was helpful hearing brief explanation of the key technologies, by category. The timeline seems well planned given the scope of work.

Reviewer 3:

The reviewer said good content, timeline, and plan covering most of the deliverables. The reviewer would have liked to see a cost comparison to a diesel baseline, not just to the high-cost gen 1 BEV. Secondly, the reviewer would like to see an energy tracking tool, how does the project move forward the kilowatt-hour/mile needed to have acceptable TCO? Finally, the speaker mentioned that energy cost is included in the 40% TCO reduction, what are the details for how the charging infrastructure and energy costs are included?

Reviewer 4:

The reviewer said this is a comprehensive program to cover all aspects of BEV deployment in Class 8 HD trucks. It is important for the freight industry to continue to have multiple options with respect to OEMs and their different approaches to providing products and distribution for this sector. The approach is methodical and well planned with incremental development and validation. The reviewer did have a concern that the 30%–40% TCO reduction is against a somewhat fluid baseline. There is not much Gen1 operating data and long-term uptime, or maintenance costs will not be available. From a customer's perspective, the reviewer mentioned venturing a guess that they would much rather understand the TCO comparison to their existing well-known diesel fleet. Finally, the program has not provided many quantifiable targets with respect to performance or duty cycle. The reviewer stated that they would like to see more details in this regard.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer remarked very early in the project, but a good plan exists.

Reviewer 2:

The reviewer said that with BEV trucks already having been put on the road, with needed equipment and data logging and driver training already well underway, technical progress is proceeding well for this period. Understanding potential challenges of supply chains, having the purchase orders for microgrid infrastructure submitted and 20% of chargers (2 out of 10) installed shows progress. Having changed the fast-charging scope due to unforeseen circumstances with the utility supplier is understandable; moving to an OEM facility for testing is a laudable alternative.

Reviewer 3:

The reviewer said this is very early in a large project. The more difficult development and hardware delivery milestones are yet to come but Gen 1 trucks and some chargers have been deployed, which is a good and necessary start. The team should address how the removal of the fast chargers from the Gen 1 scope will affect the program's ability to establish baseline performance and uptime.

Reviewer 4:

The reviewer commented PACCAR has included most of the latest technology in their plan, and also has an excellent idea to perform the FCEV study. One huge miss is the team's baseline for the TCO calculation. First, any project should only have one baseline—PACCAR has two. In addition, when questioned about this during the review, the PI stated that this baseline was undefined.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer said very good beginning of partner activity.

Reviewer 2:

The reviewer commented of course, it is still early days with this project. However, PACCAR appears to have an excellent plan for collaboration with several good partners.

Reviewer 3:

The reviewer stated at this early stage, with the work just getting started, the scoring is mainly based on the fact that collaborators for the project and its major sub-systems are on board.

Reviewer 4:

The reviewer pointed out the project team participants, particularly the fleet partners for deployment/data collection, have strong reputations for scrutinizing operational viability of new technologies as well as adopting those that prove viable. The progress shown to date is illustrative of strong collaboration. Since there was a challenge of the utility supplier reducing incentives, resulting in the decision to move megawatt charge testing to an OEM facility, it would be helpful to include in the future project outcome/report a brief summary of the facts leading to this change, as an instructional/informational tale for others to learn from.

Question 4: Please comment on the 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 broadly described but appears to be appropriate for the project.

Reviewer 2:

The reviewer said excellent, the most difficult aspects of HD BEVs are covered including battery development, e axle, sub systems, and charging.

Reviewer 3:

The reviewer said all the future work proposed is good. Having said that, PACCAR should have included more real-world fleet testing—this is one of the primary purposes of the SuperTruck program.

Reviewer 4:

The reviewer considered the scope of the project's Gen 2 and Gen 3 deployments and track testing plans highly relevant to the national research needs in this area, and they are well defined in the overview. Experience from these deployments (and testing/validation) are essential to the overall carbon reduction approach for the transportation sector. Gen 3 efforts planned to build test beds for proving out technology maturity, especially in long haul (HD) operations, where BEV implementation is particularly challenging, is a needed outcome and helpful target. In addition to the quantitative data collection in the fleet deployments, will there be some qualitative information collected from the fleets relative to successes and challenges? Driver acceptance? Experience with charging installation? Scalability for the fleets?

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer said the project is highly relevant to DOE goals and includes work in most VTO sub program areas.

Reviewer 2:

The reviewer said zero emissions medium- and HD trucks must be considered as part of the VTO's objectives of reducing the transportation sectors' carbon emissions. This project aims squarely at testing/deploying zero emissions technology, with the anticipated outcome, after on-road and test center results, helping to prove feasibility in real world environment.

Reviewer 3:

The reviewer said broadly speaking, the project supports the VTO's goal of developing affordable, efficient, and clean transportation options. The reviewer's question, more for the VTO than the project team, is whether this SuperTruck is "Super" enough? Is the project truly accelerating development of the next generation of technologies or is it riding a wave that is there to be ridden?

Reviewer 4:

The reviewer remarked that the PACCAR SuperTruck 3 project is extremely relevant. The reviewer reiterated a huge miss with the team's TCO baseline approach.

Question 6: Please provide comments on the resources of the project. 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 to complete the project in a timely fashion.

Reviewer 2:

The reviewer pointed out that trucks are expensive. Test trucks, effectively prototypes, are more expensive, and while more trucks (for more test data miles) could be desired, the reviewer considers the resources planned in this project to be sufficient. The phased approach (Gen 1, 2, and 3 trucks) incrementally builds on prior learning.

Reviewer 3:

The reviewer remarked it is difficult to ascertain at this early stage of the project.

Reviewer 4:

The reviewer was unclear why PACCAR received almost twice the funding of Volvo. The projects appear to be similar in scope.

Presentation Number: ELT286
Presentation Title: A Zero Emission Freight Future (SuperTruck 3)
Principal Investigator: Eric Bond (Volvo Trucks)

Presenter

Eric Bond, Volvo Trucks

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.

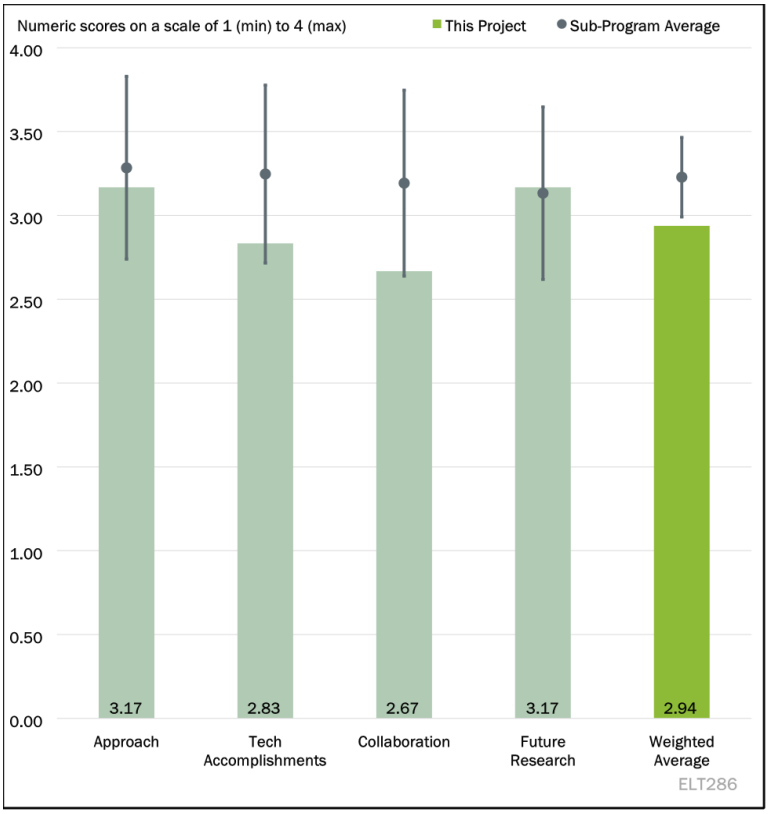

Figure 2-29 - Presentation Number: ELT286 Presentation Title: A Zero Emission Freight Future (SuperTruck 3) Principal Investigator: Eric Bond (Volvo Trucks)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer said Volvo's approach to the SuperTruck 3 program is really good. Building on the success of SuperTruck 1 and 2 is also very good. The approach would have been even better if the team had considered a hydrogen concept—at least a study.

Reviewer 2:

The reviewer cited technical barriers—it is commendable to start with modeling/analysis to test out the targets preliminarily. Also, this work builds on SuperTruck 1 and 2, which bolsters this project design. Moving from the ICE baseline to BEV drivetrain sets a high bar for HD long haul, with battery weight and size (volume) a challenge. Also, moving from 4x2 to 6x4, longer wheelbase, higher gross combination weight (per the design plan) brings the resulting vehicle on par with the mainstay highway (long-haul) tractor in operation today.

Reviewer 3:

The reviewer said the presentation severely lacks much of the needed technical details to do a fair assessment.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer said that the project is moving along. There are no details beyond, "we are still working on it." To be fair, the project started not even a year ago.

Reviewer 2:

The reviewer commented technical progress has been made. The ESS investigation is ongoing (battery, cell types, energy density/capacity, state of charge, performance and form factor) and all are included in the project. The reviewer noted the team is redesigning hood and chassis to optimize for BEV, as well as trailer design/spec changes on account of new tire sizes (new tire development by partner Michelin).

Reviewer 3:

The reviewer remarked that the technology studies performed to date are really good. However, the discussion about the compromise for tire wear versus tire rolling resistance is misleading on Slide 12. A compromise means that one of the characteristics goes down while the other characteristic goes up. This comment needs clarification. An Assumptions slide would have added more detail to the presentation.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer said Volvo has a good list of partners for collaboration. However, the team is already one full year into the project and do not yet have a fleet partner.

Reviewer 2:

The reviewer commented the initial collaboration seems well in line with expectations of DOE research funding, with anticipated work among OEM, suppliers, fleet partner (to be determined), academia and national laboratories contributing. It is very important to include in the future final report the perspectives from a fleet partner (who could be a future user of the BEV truck) on practical implementation on the road—TCO approximations, day to day operation benefits/drawbacks (charging, operating, tire management, ride height, driving, reliability of the tractor/trailer systems, etc.).

Reviewer 3:

The reviewer noted that collaborators are mentioned but it is hard to understand who is doing what between Rensselaer Polytechnic Institute and ORNL.

Question 4: Please comment on the 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 appears to know what to do next.

Reviewer 2:

The reviewer said future research is clearly defined, with proving out the simulation/analysis work of the early phase into the design and vehicle integration looking ahead (and the vehicle demonstration). The reviewer appeals for the project team to consider engaging a potential fleet customer(s), local power utility representation, and municipality (building code officials) representation to witness/be aware of and provide feedback with their perspectives/observations—either qualitative or quantitative in nature—on the vehicle demo and/or megawatt charging demonstrations, if resources allow.

Reviewer 3:

The reviewer pointed out that one of the primary purposes of the SuperTruck program is to get real-world experience. Working close with a fleet and gaining additional real-world experience should have been included in the future research.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer said the relevance of the project is clearly in line with VTO priorities. This BEV development addresses analysis, batteries, electrification, energy efficient mobility systems, and materials all in one vehicle product (as well as the supporting analysis and design development). Long haul freight a disproportionally large fraction of energy for transport, so SuperTruck 3 aims directly at the DOE goals.

Reviewer 2:

The reviewer said this project is extremely relevant. Volvo talks about improving the TCO, but does not identify a baseline for this improvement—this should be added for the next AMR.

Reviewer 3:

The reviewer said electrification.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked with funding expected to produce design and vehicle integration and demonstration of a BEV freight truck (with 400-mi range and megawatt charging system), the motor carrier movers of freight (and consumers of fuel) need this R&D and demonstration to advance acceptance and prove viability of BEVs to help meet our carbon reduction goals.

Reviewer 2:

The reviewer commented resources for this project seem to be appropriate.

Reviewer 3:

The reviewer said it is a good ratio for DOE, but still it is a lot of money, which could be used more efficiently within DOE for a smaller proof of concept.

Presentation Number: ELT287
Presentation Title: Cummins High Power Density Inverter
Principal Investigator: Santhosh Krishnamoorthi (Cummins)

Presenter

Santhosh Krishnamoorthi, Cummins

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.

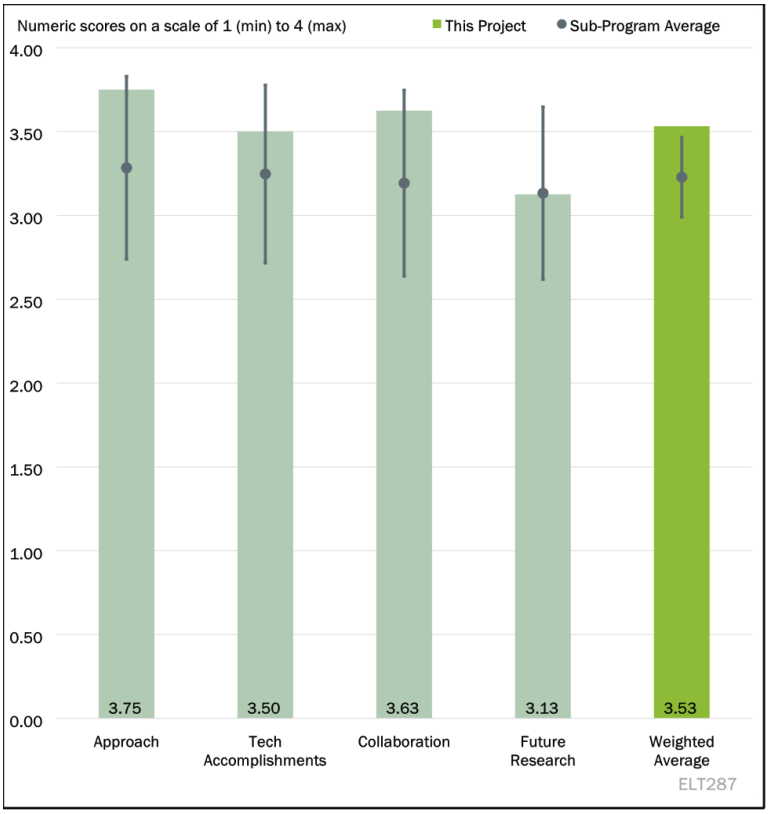

Figure 2-30 - Presentation Number: ELT287 Presentation Title: Cummins High Power Density Inverter Principal Investigator: Santhosh Krishnamoorthi (Cummins)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer said the team is developing a high-power-density inverter. The team has considered all aspects of the design—not just the power stage, but also control, sensors, capacitors, and bus bars.

Reviewer 2:

The reviewer said the project team has aligned technology to be developed to Cummins' needs while attempting to meet DOE 2025 targets for power density, cost, and reliability. The 100 kW/L target is for DC bus operation greater than 650V, therefore, selection of a near 1000V DC bus will allow a much easier way to meet 100 kW/L power-density target. It is an appropriate engineering process and the project team's approach is setting goals and then thinking through to outline various goals including cost, power-density, and durability. Use of CeraLink capacitor in inverter packaging will pose a roadblock in meeting the cost target.

Reviewer 3:

The reviewer remarked the approach to address the technical barriers is on track. The reviewer would like to see the physical testing plan and related DVP&R and under what conditions it will be performed.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer said the team has completed much of the design, at least in pieces. The team has made some important design decisions, such as the topology, though some are fairly obvious choices. With few exceptions, though, no experimental validation is available at this time. For example, the gate drive power supply has been designed and components have been ordered, but the design has not been tested yet. Still, preliminary indications are positive. There is also good progress on the reliability analysis.

Reviewer 2:

The reviewer noted the standard six switch inverter topology for 300 kW peak power was selected by analytical processes, it is simple and appropriate and as per engineering practice by automotive companies. Doable side power module design concept developed in collaboration with Virginia Tech. Gate drive supply design concept developed and optimized. However, it seems like power supply transformer could occupy undesirable level of real state inside an inverter box. A commercially available current sensor selected bus bar design was completed, however stray inductance is over 15nH, this needs to be lowered, particularly form inverter over current protection set point standpoint and safe turn-off under excessively high current. The team developed a capacitor packaging concept, and a project collaborator is evaluation EMI suppression by packaging. Manifold based heatsink design concept developed. Control board development and inverter control software development works are under progress. Inverter reliability is assessed for applications such as pickup and delivery, school bus, etc.

Reviewer 3:

The reviewer said progress is on track, but the reviewer recommended having a detailed DVP&R to consider worst-case test conditions.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer remarked the team is thoughtfully composed with an appropriate division of tasks in alignment with team member expertise. There is good evidence that the team members are working together towards common goals.

Reviewer 2:

The reviewer said strong collaboration exists in execution of project activities as the project team led by Cummins has two national laboratories and Virginia Tech as collaborators.

Reviewer 3:

The reviewer said collaboration is on track.

Question 4: Please comment on the 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 good plan for testing subsystems and integrating them. The team has identified areas where changes are expected, such as the EMI filter, as well as the challenges that they need to overcome.

Reviewer 2:

The reviewer remarked the project team has outlined future research for Fiscal Year 2023 and Fiscal Year 2024. This reviewer suggested developing a realistic commercialization pathway including a supply chain of enabling components for the proposed 300 kW peak power inverter.

Reviewer 3:

The reviewer commented an impact analysis of reliability achieved from target design based on volume of greater than 3 liters compared to the DOE target design of greater than 1 liter would be more valuable.

Reviewer 4:

The reviewer said the project needs to test on a dynamometer and vehicles to confirm objectives are met.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer said the team has set appropriate targets that are aligned with the power and power density goals of the VTO program.

Reviewer 2:

The reviewer agreed this project is relevant to the VTO subprogram in the electrification area, and the project is trying to meet DOE's 2025 targets for cost, power-density, and durability of the traction inverter.

Reviewer 3:

The reviewer said real-world applications and growth in electrification, focus on performance and cost objectives.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented effort, progress, and plans are commensurate with the resource allocation.

Reviewer 2:

The reviewer said the project has necessary resources and research funds.

Reviewer 3:

The reviewer said resources are on track.

Presentation Number: ELT288
Presentation Title: Scalable Ultra Power-Dense Extended Range (SUPER) Inverter
Principal Investigator: Harsha Nanjundaswamy (Borg Warner)

Presenter

Harsha Nanjundaswamy, Borg Warner

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.

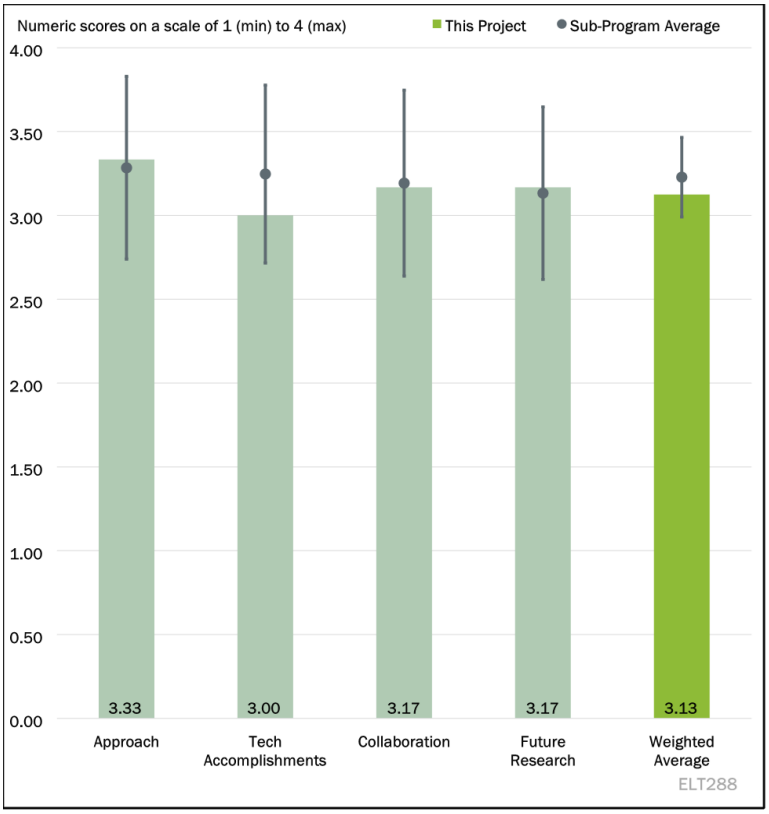

Figure 2-31 - Presentation Number: ELT288 Presentation Title: Scalable Ultra Power-Dense Extended Range (SUPER) Inverter Principal Investigator: Harsha Nanjundaswamy (Borg Warner)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer said this project integrates a new device package concept with a variety of other supporting elements, such as a safety application-specific integrated circuit (ASIC) and new capacitors.

Reviewer 2:

The reviewer commented the presenter repeatedly stressed the fact that commercialization, high speed, and high-volume manufacturing were always kept in focus. This is very good, because this ensures that the project has a much better chance of seeing the light of day. The only slight concern is that, with the hyper-focus on commercialization, are technologies and designs that may be potentially game changing being ignored? If the purpose of this project is to continue development of internal projects that were already in progress, then the intent of the funding is not quite satisfied.

Reviewer 3:

The reviewer expected to see a detailed timeline and test cadence based on DVP&R.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer said this project is expected to yield a real-world production application with key performance and cost metrics.

Reviewer 2:

The reviewer said the team has made excellent progress on design tasks, including a new device package, a new cold plate, and new capacitors. The team is evaluating thermal interface material (TIM) options. The electrical architecture incorporates an ASIC that was already in development, providing the first demonstration. The entire design is oriented towards high-volume manufacturing. At this time, very limited experimental results are available, however, with an emphasis on simulations.

Reviewer 3:

The reviewer noted that all the required design/concept reviews required for budget period 1 appear to be on track. The next budget periods are the meat of the project, and it will be interesting to see the outcome over the next two budget periods. The reviewer said targets for reliability need to be clarified. Fifteen years/300,000 miles is a good target to have, but without a clear definition of the mission profile, this does not carry much meaning. For instance, using 300,000 miles of Federal Test Procedure city and highway cycles as a reliability target is not necessarily appropriate, because there are far more severe real world driving events that take place routinely. It is also not clear what the target for efficiency is, and over what drive cycle the efficiency would be measured.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer noted there is a very good cross section of academia, national laboratories, and suppliers involved in the project.

Reviewer 2:

The reviewer said the work up to this point is well-coordinated with an appropriate division of tasks. However, future engagement with Virginia Tech Center for Power Electronics Systems is unclear.

Reviewer 3:

The reviewer suggested having a customer focused application in mind as the project continues.

Question 4: Please comment on the 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 project seems to be on track for full validation. As previously noted, the role of Virginia Tech in future research is unclear.

Reviewer 2:

The reviewer remarked so far, during the budget period one, mainly the down-selection process appears to have been completed with no actual hardware being built. The next two budget periods will cover all of the prototype building and validation. However, the issues that raised in the response to Question 4 need to be addressed.

Reviewer 3:

The reviewer said base the testing and validation on a detailed DVP&R.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer said the project directly addresses inverter power and power density with an innovative packaging approach and other components. Importantly, it also addresses cost directly.

Reviewer 2:

The reviewer pointed out that space is always a premium when designing electric drive units, and an increased power density inverter definitely helps in easing the packaging issues that are faced.

Reviewer 3:

The reviewer noted efficiency and cost objectives are critical to meet.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said the project is appropriately scaled to the available resources.

Reviewer 2:

The reviewer remarked resources are sufficient.

Reviewer 3:

The reviewer said resources are on track.

Presentation Number: ELT290
Presentation Title: Behind-the-Meter-Storage
Principal Investigator: Matthew Keyser (National Renewable Energy Laboratory)

Presenter

Matthew Keyser, National Renewable Energy 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 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.

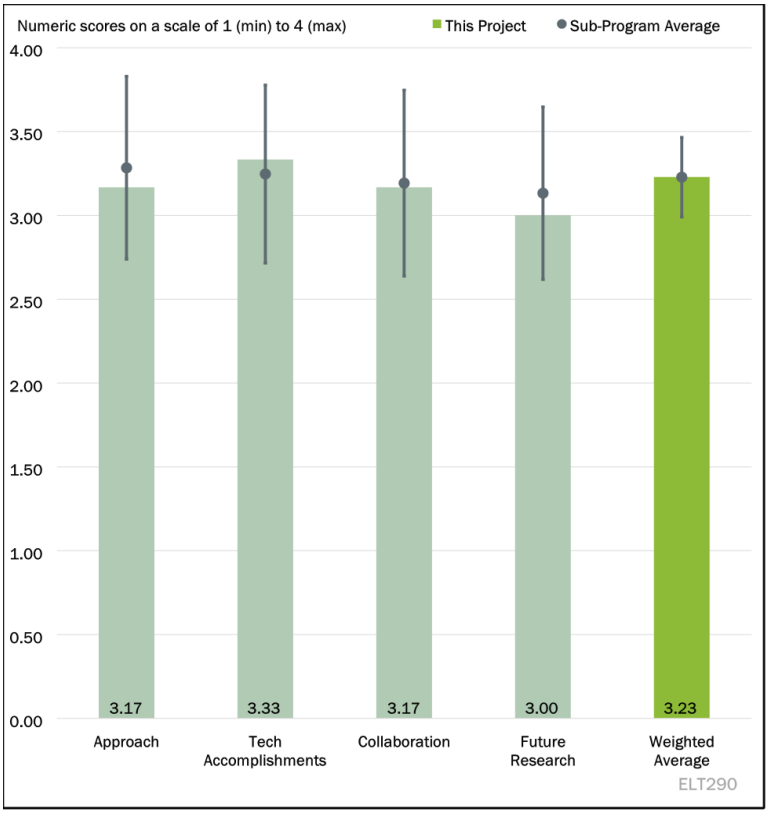

Figure 2-32 - Presentation Number: ELT290 Presentation Title: Behind-the-Meter-Storage Principal Investigator: Matthew Keyser (National Renewable Energy Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer noted the critical barrier for this project is the buffer battery ESS and the project team addressed this by focusing most of the research on battery chemistry, cycle life, and battery safety research. The project has a clear timeline, specific milestones, and well-designed testing plans. When the original project plan was prepared in 2018, it correctly reflected the ESS industry at that time: most ESS still used cells designed for EVs and nickel manganese cobalt (NMC) was the major ESS battery chemistry, but the ESS battery technology and market has changed dramatically. Since 2021, lithium iron phosphate (LFP) has become the dominant chemistry due to cost and safety reasons and NMC is losing most of its ESS market share. And the lithium titanium oxide (LTO) battery has only less than 1% of the lithium-ion battery market and is not commonly used for ESS. In the future, LTO could potentially take some niche ESS or commercial electric vehicle market that require very long cycle life, but this will not be certain due to its low energy density and higher cost. Thus, if allowed, maybe the project plan could be modified with time accordingly.

Reviewer 2:

The reviewer advised the first step in this project should have been to make an attempt to determine the number of charging ports that are typically needed in a building as a function of square footage of occupancy or number of occupants in the building under certain assumptions, such as, a ratio of EVs per occupants and a percentage of occupants with EVs which would need to be charged during the time they are occupying the building. The assumption of fast charging (e.g., for 200-mile range in 10 mins.) rather than slow (or overnight

charging) is reasonable because the building is assumed not to be for residential purposes but for office, business, or other commercial use. The reviewer advised the second step to make things simple is to start with locating the battery ESS outside the building and once that is optimized, work towards putting it inside the building. Third, the reviewer questions whether battery development (including strings of batteries) should be a part of this project. Battery development should be left to the scientists/engineers who specialize in that particular area, and this project should take the most optimum stationary battery that has been developed as the starting point for this project. Fourth, the reviewer likes the idea of looking at five different topologies, active vs. passive state of charge balancing, utilization of isolated dual-active bridge converters, etc.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer said good progress has been made in areas including high nickel NMC, lithium-ion manganese oxide (LMO)/LTO cell cycle life analysis, small multi-cell module safety testing, different types of building load profiles, ESS/photovoltaic design across climates and utility rate schedules, etc.

Reviewer 2:

The reviewer was not clear when the PI knew that cobalt is fairly limited in availability. If it was known at the beginning of the project, then the project should have started off with LMO/LTO cells instead of either NMC622/graphite or NM/LTO cells. That would have saved a lot of time, perhaps 2–3 years could have been saved.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer said the role and responsibility are very clear for each of the of 5 national laboratories involved. Collaboration or close communication between national laboratories and industry like more frequent U.S. DRIVE update meetings could help adjust the project plan based on the changing ESS market and latest commercial ESS technologies.

Reviewer 2:

The reviewer said the collaboration team does not include building architects and engineers who have the expertise in designing fire walls and fire suppression systems as well as mitigating risk. There should have been a due diligence attempt to search for building architect/engineers who have incorporated battery ESSs in buildings already. For example, there may be sufficient designs for firewalls and fire suppression systems that could contain or control thermal runaways totally within the firewalls without requiring research and development on thermal control and management of batteries at the cell level, module level, pack level and rack level.

Question 4: Please comment on the 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 most future work listed on Slide 23 on battery management system (BMS) look good. The reviewer suggested placing priority on the work related to ESS safety like sensing technology, BMS safety features, etc. One recommendation for future work on battery development: Plenty of work has been done on LTO and NMC/Gr batteries in this project. Suggest future work focus more on LFP, especially safety design of large commercial LFP cells, modules, and packs. For this project, the reviewer suggested balance the total

effort spent on battery development and focus more on the safe use of ESS as part of the behind the meter (BTM) system: solar, thermal storage, smart building, EVSE, etc.

Reviewer 2:

The reviewer indicated that the project goals, objectives, and targets are not well-defined and specific; rather they are very nebulous and murky. The PI should have articulated specific goals, objectives, and targets. Just telling reviewers that the project needs to address the barriers of cost, performance, and safety is insufficient. In what particular area or aspect is the cost too high? What performance needs to be improved? What safety needs to be improved (e.g., are all thermal runaways to be eliminated)?

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer said this project is quite relevant to many VTO subprograms such as XFC, Electrification, Mobility, etc.

Reviewer 2:

The reviewer remarked the project is relevant, but premature. The reviewer really does not think there is enough demand (i.e., demand has not reached the tipping point) for EVs to start incorporating charging stations as part of building infrastructure.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said enough resources are provided from the world-leading national laboratories.

Reviewer 2:

The reviewer thought $2.4 million is way more than needed for this project.

Presentation Number: ELT291
Presentation Title: Enabling Extreme Fast Charging with Energy Storage
Principal Investigator: Jonathan Kimball (Missouri University S&T)

Presenter

Jonathan Kimball, Missouri University 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.

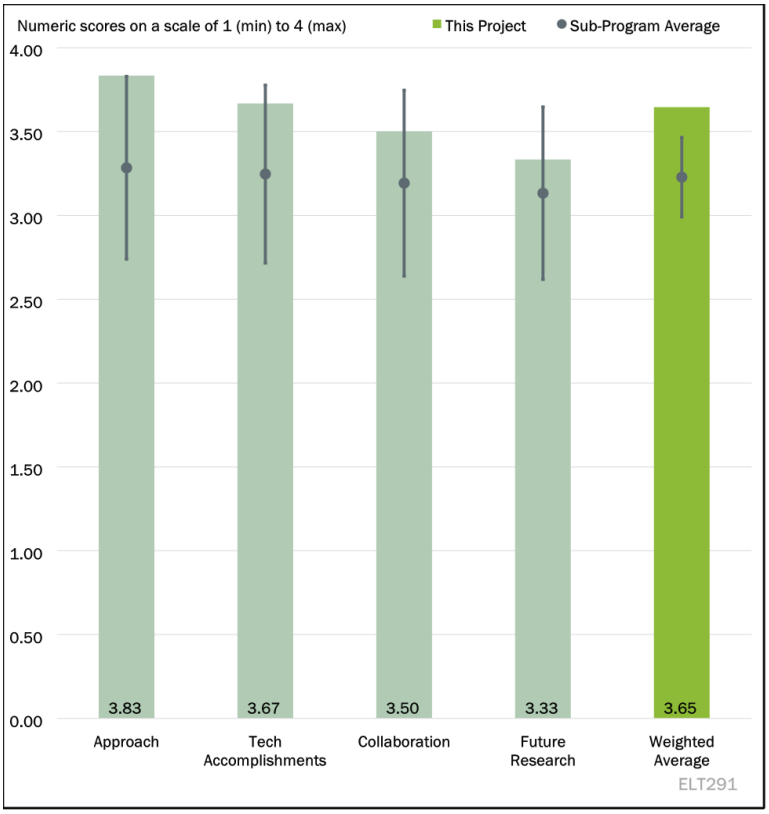

Figure 2-33 - Presentation Number: ELT291 Presentation Title: Enabling Extreme Fast Charging with Energy Storage Principal Investigator: Jonathan Kimball (Missouri University S&T)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer said that the university led project's workflow is logical and as per engineering practices. Early on the project team placed focused efforts on a proof-of-concept followed by full-scale prototype resulting in a pathway for system integration and field testing to evaluate developed technology in a near real-world application. Power conversion system is designed using well known concept of dual-active bridge.

Reviewer 2:

The reviewer said this project clearly focuses on numerous technical barriers including reduced battery degradation during high-speed charging and reducing grid impacts during high-power charging.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer said clear technical progress has been accomplished after the necessary technical shift to using 480V in place of 1.5kV.

Reviewer 2:

The reviewer said the workflow for the proposed extreme fast charger with energy storage includes assessment of grid compatibility, development of power conversion, and battery charging. Control system of overall power conversion system is included in the projects' AMR report. As per project report and AMR

presentation, project team utilizes grid, energy storage, and network of vehicles in overall eco system of XFC charger and their locations to suppress power quality and power availability impacts. Cost analysis is carried out by project team indicating 18.87% cost saving. A low voltage prototype was developed and tested. The reason for falling back on low voltage prototype was unavailability for the medium voltage devices. The project team developed a Raspberry Pi based supervisory control system and outlined future work. A 1MW station prototype pictures are included in project's AMR report and 100kVA charging current waveforms also included in the project's AMR report. Constant lithium plating current (constant dQ_{Li}/dt) constant voltage (CQtCV) charging algorithm is described in the project's AMR report. Single Module XFC Thermal Testing carried out and temperature data included in the project's AMR report.

Question 3: Please comment on 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?

Reviewer 1:

The reviewer said strong collaboration exists in execution of project activities.

Reviewer 2:

The reviewer remarked the project has assembled good partners that cover all the technical areas required for a successful project.

Question 4: Please comment on the 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 project is currently finalizing integration and field testing followed by plan for analyzing field results.

Reviewer 2:

The reviewer remarked the proposed future work appears to list the previous completed accomplishments from budget period 1 and budget period 2. The budget period 3 tasks work are also listed. Consider future work to include a field demonstration of this charging infrastructure with an electrified fleet to verify the successful benefits even during edge use cases such as a wide range in ambient temperature, fleet utilization (charge time, duration, duty-cycle), and variable distribution feeder conditions.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer said this project is relevant to VTO's sub-program in electrification and will accelerate adoption of EVs.

Reviewer 2:

The reviewer stated the project supports the objectives by improving battery resiliency during fast recharging while reducing grid impacts.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said the project has necessary resources and research funds.

Reviewer 2:

The reviewer remarked that this project successfully completed the deliverables with the allocated resources.

Acronyms and Abbreviations – ELT

Abbreviation	Definition
3D	Three-dimensional
AAM	American Axle and Manufacturing
AC	Alternating current
ACM	American Center for Mobility
AMR	Annual Merit Review
ANL	Argonne National Laboratory
ASIC	Application-specific integrated circuit
ASPIRE	Advancing Sustainability through Powered Infrastructure for Roadway Electrification
ATD	ATEAM Transmission Distribution
ATEAM	Agent-based Transportation Energy Analysis Model
BEV	Battery electric vehicle
BGE	Baltimore Gas and Electric
BMS	Battery management system
BTM	Behind the meter
CARB	California Air Resources Board
CIM	Common information model
CNG	Compressed natural gas
CQtCV	Constant lithium plating current (constant dQ_{Li}/dt) constant voltage
DAB	Dual active bridge
DBC	Direct bonded copper
DC	Direct current
DCFC	Direct current fast charger
DER	Distributed energy resource(s)
DHAM	Dual rotor homopolar AC machine
DOE	U.S. Department of Energy
DRIVE	U.S. DRIVE
DVI	Drive vehicle interface
DVP&R	Design validation plan and report
DWPT	Dynamic wireless power transfer

Abbreviation	Definition
EDM	Electric drive machine
ELT	VTO Electrification Technologies subprogram
EERE	Office of Energy Efficiency and Renewable Energy
EMC	Electromagnetic compatibility
EMF	Electromagnetic field
EMI	Electromagnetic interference
i-EMS	Intelligent energy management system
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ESS	Energy storage system
EV	Electric vehicle
EVSE	Electric vehicle supply equipment
FCET	Fuel cell electric truck
FCEV	Fuel cell electric vehicle
FTP	Federal Test Procedure
GHG	Greenhouse gas
H2	Hydrogen
HATCI	Hyundai America Technical Center, Inc
HD	Heavy-duty
HRE	Heavy rare earth
HV	High voltage
ICE	Internal combustion engine
ID	Identification
IEC	International Electric Code
IGBT	Insulated gate bipolar transistor
IIMo	Institute of Innovative Mobility (Germany)
IIT	Illinois Institute of Technology
INL	Idaho National Laboratory
IPM	Integrated power module
kW	Kilowatt
LFP	Lithium iron phosphate

Abbreviation	Definition
LLC	Limited liability corporation
LMO	Lithium-ion manganese oxide
LTO	Lithium titanium oxide
MCS	Megawatt charging system
MV	Medium voltage
MVA	Megavolt-ampere
MW	Megawatt
NCSU	North Carolina State University
NHTSA	National Highway Traffic Safety Administration
NMO	Nickel manganese oxide
NMC	Nickel manganese cobalt
NMC622	6:2:2 ratio nickel manganese cobalt oxide
NREL	National Renewable Energy Laboratory
NSP	Network service provider
NYPA	New York Power Authority
ODBC	Organic direct bonded copper
OEM	Original equipment manufacturer(s)
ORNL	Oak Ridge National Laboratory
PEV	Plug-in electric vehicle
PECO	Formerly Philadelphia Electric Company
PI	Principal investigator
PM	Permanent magnet
R&D	Research and development
RDD&D	Research, development, deployment, and demonstration
SAE	SAE International, formerly known as the Society of Automotive Engineers
SCAQMD	South Coast Air Quality Management District
SCM	Smart charge management
SEMS	Site energy management system
SiC	Silicon carbide
SSCB	Solid-state circuit breaker

Abbreviation	Definition
SST	Solid-state transformer
SUNY	The State University of New York
SUPER	Scalable ultra power-dense extended range
T	Tesla
TCO	Total cost of ownership
TIM	Thermal interface material
TPG	Thermal pyritic graphite
TRL	Technology readiness level
TTSI	Total Transportation Services, Inc.
UPER	Universal power electronics regulator
US06	EPA US06, also known as the Supplemental Federal Test Procedure
SFTP	Supplemental Federal Test Procedure
V2G	Vehicle to grid
VGI	Vehicle grid integration
VTO	Vehicle Technologies Office
VTTI	Virginia Tech Transportation Institute
WAVE	Wireless Advanced Vehicles Electrification
WBG	Wide bandgap
WFSM	Wound-field synchronous machine
WLTC	Worldwide Harmonized Light Vehicles Test Cycle
WPT	Wireless power transfer
WXFC	Wireless extreme fast charge
XFC	Extreme fast charge
XIL	Everything-in-the-loop
ZECT	Zero emission cargo transport