# 4. Electrification

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

The VTO Electrification Technologies subprogram supports the decarbonization of transportation across all modes, serves to increase American advancement/manufacturing of battery technology, and creates good paying jobs with the free and fair chance to join a union and bargain collectively. The subprogram supports research with partners in academia, national laboratories, and industry covered under the Energy Storage Grand Challenge key priority and distinct crosscuts. The Energy Storage Grand Challenge encompasses research and development (R&D) across electrification including electric vehicle charging infrastructure. The Critical Minerals crosscut aims to realize electric drive motor innovations through high energy product magnet R&D to reduce or eliminate heavy rare earth magnet materials. Grid Modernization continues to develop Smart Charge Management technologies for fleets, including medium and heavy vehicles to provide more advanced grid services such as resilience of the charging network and continuity of grid and emergency services operations during disruptive events.

The Electric Drive R&D activity supports early-stage R&D for extreme high-power density motors that have the potential to enable radical new vehicle architectures by dramatic volume/space reductions and increased durability and reliability. Reduce the cost of electric traction drive through core research of motors, high-density integration technologies, leveraging high performance computing for modeling and optimization, and utilizing new materials for high-density electric motors. Approaches will include novel circuit topologies and new materials for high-density electric motors. Electric traction drive system integration based on electric motor innovations will also be a priority.

The Electrification R&D activity supports early-stage R&D to understand the potential impacts on, and benefits of, plug-in electric vehicle (PEV) charging to the Nation's electric grid. This research will inform the development of communication and cybersecurity protocols; enable industry to enhance the interoperability between charging equipment, the on-board vehicle charger, and charging networks; and foster technology innovations to improve PEV refueling through extreme fast charging. Core research focuses on developing smart charging, extreme fast charging, and wireless charging technologies for reliable and cost-effective charging of light-, medium-, and heavy-duty electric vehicles. This includes the research of technologies related to cybersecurity of electric vehicle charging/supply equipment, and integration with the electric grid.

## Project Feedback

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

**Table 4-1 – Project Feedback**

| Presentation ID | Presentation Title | Principal Investigator (Organization) | Page Number | Approach | Technical Accomplishments | Collaborations | Future Research | Weighted Average |
|---|---|---|---|---|---|---|---|---|
| elt094 | Development and Demonstration of Medium-and-Heavy-Duty Plug-In Hybrid Work Trucks † | John Petras (Odyne Systems) | 4-8 | 3.50 | 3.50 | 3.75 | 3.75 | 3.56 |
| elt158 | Zero-Emission Cargo Transport II: San Pedro Bay Ports Hybrid & Fuel-Cell Electric Vehicle Project | Seungbum Ha (South Coast Air Quality Management District (SCAQMD)) | 4-11 | 3.00 | 2.88 | 3.50 | 3.25 | 3.03 |
| elt179 | Low Cost, High-Performance, Heavy Rare-Earth-Free 3-In-1 Electric Drive Unit | David Crecelius (American Axle & Manufacturing ) | 4-15 | 3.43 | 3.29 | 3.21 | 3.36 | 3.32 |
| elt188 | Bi-Directional Wireless Power Flow for Medium-Duty, Vehicle-to-Grid Connectivity | Omer Onar (Oak Ridge National Laboratory) | 4-20 | 3.50 | 3.33 | 3.17 | 3.33 | 3.35 |
| elt197 | High Power and Dynamic Wireless Charging of Electric Vehicles | Veda Galigekere (Oak Ridge National Laboratory) | 4-23 | 3.60 | 3.50 | 3.60 | 3.30 | 3.51 |
| elt208 | Highly Integrated Power Module | Lincoln Xue (Oak Ridge National Laboratory) | 4-28 | 3.60 | 3.60 | 3.70 | 3.30 | 3.58 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| elt209 | High-Voltage, High-Power Density Traction-Drive Inverter | Gui-Jia Su (Oak Ridge National Laboratory) | 4-32 | 3.60 | 3.60 | 3.60 | 3.50 | 3.59 |
| elt210 | Development of Next-Generation Vertical Gallium-Nitride Devices for High-Power Density Electric Drivetrain | Andrew Binder (Sandia National Laboratories) | 4-36 | 3.38 | 3.75 | 3.63 | 3.25 | 3.58 |
| elt215 | Permanent Magnets Without Critical Rare Earths to Enable Electric Drive Motors with Exceptional Power Density | Iver Anderson (Ames Laboratory) | 4-39 | 3.50 | 3.33 | 3.33 | 3.17 | 3.35 |
| elt216 | Isotropic, Bottom-Up Soft Magnetic Composites for Rotating Machines | Todd Monson (Sandia National Laboratories) | 4-42 | 3.38 | 3.38 | 3.38 | 3.25 | 3.36 |
| elt217 | Integrated/Traction Drive Thermal Management | Bidzina Kekelia (National Renewable Energy Laboratory) | 4-46 | 3.33 | 3.17 | 3.83 | 3.33 | 3.31 |
| elt218 | Advanced Power Electronics Designs-Reliability and Prognostics | Doug DeVoto (National Renewable Energy Laboratory) | 4-49 | 3.50 | 3.50 | 3.40 | 3.50 | 3.49 |
| elt221 | Integrated Electric Drive System | Shajjad Chowdhury (Oak Ridge National Laboratory) | 4-53 | 3.50 | 3.50 | 3.10 | 3.40 | 3.44 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| elt236 | Direct-Current Conversion Equipment Connected to the Medium-Voltage Grid for Extreme Fast Charging Utilizing Modular and Interoperable Architecture | Watson Collins (EPRI) | 4-57 | 3.50 | 3.50 | 3.50 | 3.00 | 3.44 |
| elt237 | Enablig Extreme Fast Charging with Energy Storage † | Jonathan Kimball (Missouri S&T) | 4-59 | 3.67 | 3.50 | 3.67 | 3.17 | 3.52 |
| elt238 | Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State Direct-Current Protection | Srdjan Lukic (North Carolina State University) | 4-62 | 3.63 | 3.38 | 3.00 | 2.88 | 3.33 |
| elt239 | High-Power Inductive Charging System Development and Integration for Mobility | Omer Onar (Oak Ridge National Laboratory) | 4-66 | 4.00 | 3.83 | 3.17 | 3.50 | 3.75 |
| elt240 | Wireless Extreme Fast Charging for Electric Trucks (WXFC-Trucks) | Mike Masquelier (WAVE) | 4-69 | 3.38 | 3.25 | 3.50 | 3.25 | 3.31 |
| elt241 | High-Efficiency, Medium-Voltage Input, Solid-State, Transformer-Based 400-kilowatt (kW)/1000-V/400-A Extreme Fast Charger for Electric Vehicles | Charles Zhu (Delta Electronics) | 4-73 | 3.67 | 3.33 | 3.83 | 3.33 | 3.48 |
| elt252 | Wound-Field Synchronous Machine-System Integration toward Increased Power Density and Commercialization | Lakshmi Iyer (Magna Services of America Inc) | 4-76 | 2.75 | 2.75 | 3.00 | 3.00 | 2.81 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| elt253 | Motor with Advanced Concepts for High-Power Density and Integrated Cooling for Efficiency Machine | Jagadeesh Tangudu (United Technologies Research Center) | 4-80 | 2.75 | 2.50 | 2.63 | 2.63 | 2.59 |
| elt255 | Cost-Effective, Rare-Earth-Free, Flux-Doubling, Torque-Doubling, Increased Power Density Traction Motor with Near-Zero Open-Circuit Back-Electromagnetic Field and No-Cogging Torque | Soma Essakiappan (University of North Carolina at Charlotte) | 4-84 | 3.00 | 3.00 | 3.00 | 3.17 | 3.02 |
| elt256 | Amorphous Metal Ribbons and Metal Amorphous Nanocomposite Materials Enabled High-Power Density Vehicle Motor Applications | Mike McHenry (Carnegie Mellon University) | 4-87 | 2.75 | 3.25 | 3.00 | 3.13 | 3.08 |
| elt258 | Grid-Enhanced, Mobility-Integrated Network Infrastructures for Extreme Fast Charging (GEMINI-XFC) | Andrew Meintz (National Renewable Energy Laboratory) | 4-91 | 2.50 | 2.50 | 2.33 | 2.67 | 2.50 |
| elt259 | Development and Commercialization of Heavy-Duty Battery Electric Trucks Under Diverse Climate Conditions | Marcus Malinosky (Daimler Trucks North America) | 4-95 | 3.38 | 3.25 | 3.38 | 3.33 | 3.31 |
| elt260 | Improving the Freight Productivity of a Heavy-Duty, Battery Electric Truck by Intelligent Energy Management | Teresa Taylor (Volvo) | 4-99 | 3.50 | 3.50 | 3.50 | 3.38 | 3.48 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| elt261 | High-Efficiency Powertrain for Heavy-Duty Trucks using Silicon Carbide Inverter | Steve Peelman (Ricardo) | 4-103 | 3.33 | 3.17 | 3.17 | 3.50 | 3.25 |
| elt262 | Long-Range, Heavy-Duty Battery-Electric Vehicle with Megawatt Wireless Charging | Stan DeLizo (Kenworth) | 4-107 | 3.00 | 2.50 | 3.17 | 2.67 | 2.73 |
| elt263 | Low-Cost Rare-Earth-Free Electric Drivetrain Enabled by Novel Permanent Magnets, Inverter, Integrated Design and Advanced Thermal Management | Ayman El-Refaie (Marquette) | 4-110 | 3.75 | 3.50 | 3.25 | 3.50 | 3.53 |
| elt264 | Demonstration of Utility Managed Smart Charging For Multiple Benefit Streams | Joe Picarelli (Exelon/Pepco Holdings Inc.) | 4-114 | 3.63 | 3.38 | 3.50 | 3.00 | 3.41 |
| elt265 | A Secure and Resilient Interoperable Smart Charging Management (SCM) Control System Architecture for Electric Vehicle's-At-Scale | Duncan Woodbury (Dream Team LLC) | 4-119 | 2.83 | 2.33 | 2.67 | 2.67 | 2.54 |
| elt266 | Next Generation Profiles: High Power Charging Characterization | Dan Dobrzynski (Argonne National Laboratory) | 4-122 | 3.20 | 3.60 | 3.70 | 3.20 | 3.46 |
| elt274 | eMosaic: Electrification Mosaic Platform for Grid-Informed Smart Charging Management | David Coats (ABB) | 4-127 | 3.17 | 2.83 | 3.00 | 3.17 | 2.98 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| elt277 | Electric Vehicle Integrated Safety, Intelligence, OperatioNs (eVision) | Madhu Chinthavali (Oak Ridge National Laboratory) | 4-130 | 3.33 | 3.50 | 3.33 | 3.33 | 3.42 |
| elt278 | Electric Vehicles (EVs) at Scale Laboratory Consortium | Andrew Meintz (National Renewable Energy Laboratory) | 4-133 | 3.00 | 3.20 | 3.10 | 3.10 | 3.13 |
| **Overall Average** | | | | **3.33** | **3.27** | **3.31** | **3.22** | **3.29** |

† Denotes poster presentation.

**Presentation Number: elt094**
**Presentation Title: Development and Demonstration of Medium-and-Heavy-Duty Plug-In Hybrid Work Trucks**
**Principal Investigator: John Petras, Odyne Systems**

***Presenter***

John Petras, Odyne Systems

***Reviewer Sample Size***

A total of two reviewers evaluated this project.

***Project Relevance and Resources***

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

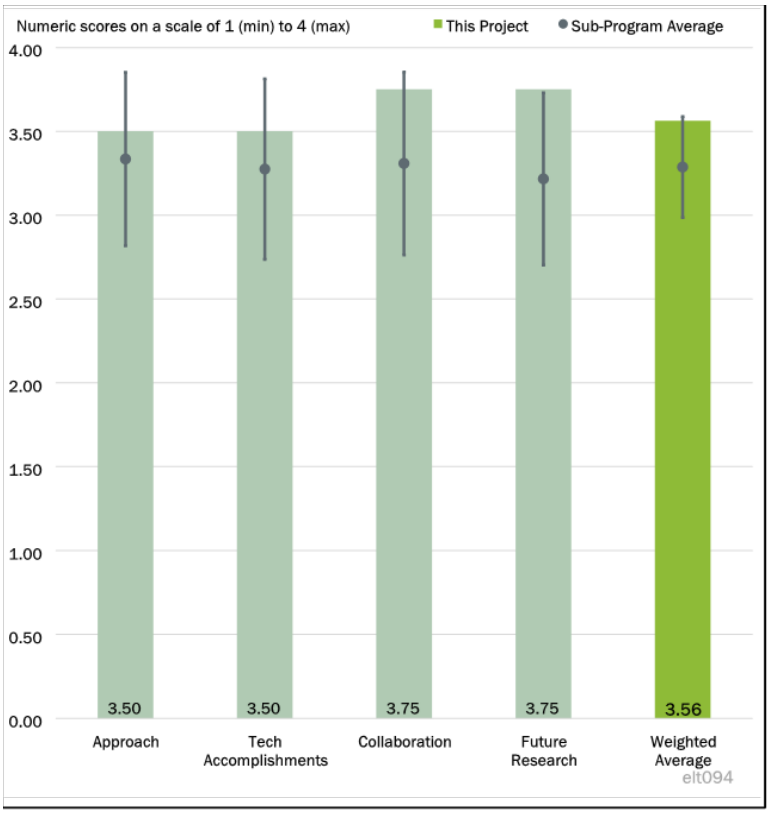


Figure 4-1 - Presentation Number: elt094 Presentation Title: Development and Demonstration of Medium-and-Heavy-Duty Plug-In Hybrid Work Trucks Principal Investigator: John Petras, Odyne Systems

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

**Reviewer 1**

The reviewer identified the following as strengths. The objective of the Odyne project is to develop and demonstrate a modular plug-in hybrid electric vehicle (PHEV) medium-heavy duty work truck system with greater than 50% reduction in fuel consumption when compared to a conventional diesel vehicle baseline. The reviewer said the Odyne project approach is excellent. It incorporates hybrid power through the existing power take-off port, launch assist/regenerative braking while driving, and all-electric application power for stationary work with no changes to the base powertrain. The approach incorporates a three-component modular design which allows installation on most chassis and applications. Options exist for a second battery and exportable power. The reviewer noted that a strong, conventional development approach has been followed: including R&D, test/evaluation, demonstration, and subsequently commercialization. Odyne is working with chassis original equipment manufacturers (OEMs), final stage and equipment manufacturers, and fleet customers to understand the diverse requirements of the work truck market. The reviewer noted that Odyne is working with national labs to analyze the work truck cycle and optimize driving and full day hybrid driving/work strategies, and that efforts continue to lower costs and expand applicability. The reviewer said there were no readily apparent weaknesses.

**Reviewer 2**

The reviewer said the approach is a clever way to electrify conventional work vehicles when bespoke hybrid powertrains may not be economically viable.

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

**Reviewer 1**

The reviewer remarked project goals are substantially on track, with demonstration hardware ready for deployment.

**Reviewer 2**

The reviewer identified as strengths the project completed technical and design development of the system.

In December 2021 (budget period 2), through dynamometer testing and duty cycle analysis, the team demonstrated greater than 40% improvement in driving fuel economy and predicted greater than 50% reduction in average annual fuel use. For driving fuel economy assessment, the chassis was tested at the National Renewable Energy Laboratory (NREL) with 3 drive cycles for work truck operation and two hybrid on-road drive cycles (mild and aggressive). The mild strategy yielded a 9%-23% improvement in fuel economy, while the aggressive strategy yielded a 69%-75% fuel economy improvement. The stationary work cycle yielded an 80%-99% reduction in fuel use and emissions. The simulated full year fuel savings for the Odyne PHEV Work Truck was 54.6%. The team completed build, delivered demonstration vehicles, and began training / support to demonstration fleet (early 2022). The reviewer identified as a major Accomplishment how this project is indicating commercial success. Three Odyne customers have ordered PHEV vehicles in new Odyne markets including cranes, city refuse, and electrified street sweeper.

The reviewer identified as a weakness how the project mentions continuing efforts to reduce cost, but no specifics are provided.

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

**Reviewer 1**

The project tasks are assigned to different partners according to expertise and the collaboration has achieved the desired results.

**Reviewer 2**

The reviewer said project is collaboration is outstanding. A broad, diverse set of project participants have been included and deeply integrated throughout the project evolution. This includes national labs (NREL and Oak Ridge National Laboratory [ORNL]), expert powertrain and transmission (Allison) and battery system (Ricardo) firms, a public utility (Tacoma Public Utilities) for demonstration, and project cost share partner (South Coast Air Quality Management District [SCAQMD]). There are no readily apparent gaps nor weaknesses in the project team.

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

**Reviewer 1**

The reviewer remarked next steps support and complete the project objectives. Application to all-electric chassis is a bit fuzzy (would seem to be a different project at that point).

**Reviewer 2**

The reviewer identified as strengths continuing to work with Tacoma Public Utilities to deploy and monitor the demonstration vehicles; collecting insights from operators and fleet managers; completing installation of

telematics system, collecting data, and optimizing; and beginning development of next generation work truck system for an all-electric chassis being introduced into the market. The reviewer said that there were no readily apparent weaknesses.

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

**Reviewer 1**

The reviewer said the project is developing technology that enables electrification of work vehicles. This also furthers the energy efficiency goals of VTO.

**Reviewer 2**

The reviewer noted that medium- and heavy-duty work trucks consume over 50% of their fuel during stationary jobsite work and idle conditions. Current efficiency and hybridization efforts by large truck manufacturers focus on driving efficiency as opposed to stationary fuel savings opportunities. Odyne has created a modular hybrid electrification system applicable to a large portion of the medium- and heavy-duty truck market that has demonstrated a full duty/driving cycle fuel economy savings of over 50%. The reviewer said this will expand its application opportunities with concomitant energy and environmental benefits.

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

**Reviewer 1**

The reviewer remarked resources provided for this project have been sufficient to conduct the scope of project activities. The project incorporated 50% cost share.

**Reviewer 2**

The reviewer said the project is on track for completion and appears to be sufficiently funded.

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

### *Presenter*

Seungbum Ha, SCAQMD

### *Reviewer Sample Size*

A total of four reviewers evaluated this project.

### *Project Relevance and Resources*

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

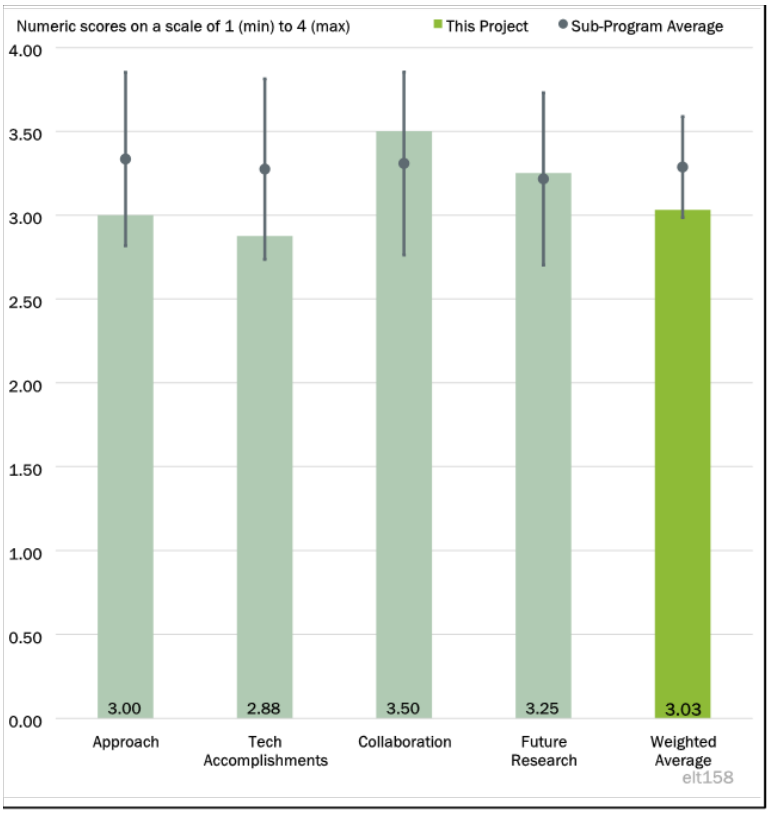


Figure 4-2 - Presentation Number: elt158 Presentation Title: Zero-Emission Cargo Transport II: San Pedro Bay Ports Hybrid & Fuel-Cell Electric Vehicle Project Principal Investigator: Seungbum Ha, South Coast Air Quality Management District

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

**Reviewer 1**

The reviewer said the technical barriers are addressed directly and the project is well designed. The timeline is reasonably planned and has adapted appropriately to real-world events.

**Reviewer 2**

The reviewer remarked the project does a good job at integrating the few fuel cell prototypes currently available into a real work setting to evaluate the benefit of the technology. The team has installed hydrogen fueling stations to support deployment of the vehicles in the field. The documentation of each vehicle's performance is useful as it helps convey what is required to meet the duty cycle.

**Reviewer 3**

The reviewer is puzzled by five important aspects in the approach to performing the work.

First, the principal investigator indicated that he would complete the development of the Cummins fuel cell truck in 2022. The principal investigator does not present any charts showing that this has been accomplished. This statement was repeated in 2021.

Second, the principal investigator needs to show a milestone chart for each of the five projects listed on Slide 2. The reviewer has no idea of the progress on each project, let alone what are the specific goals for each of the five projects and thus what needs to be accomplished.

Third, Slide 8 seems to show the same data as that which was presented in 2021. There is no need to repeat this data unless a point is being made, and the reviewer does not see the point being made. If the data differs from that presented in 2021, please explain the differences.

Four, Slide 9 shows that the principal investigator understands the difference between battery-dominant and fuel-cell dominant vehicles as each one affects a vehicle's range, but he needs to show how this relates to each of the six projects. For example, is the approach to the development of the truck in project #1 battery-dominant or fuel-cell dominant and why is range important or not important?

Five, the principal investigator needs to do a better job of documenting the causes for the excessive downtime in the fuel cell vehicles under development because they stymie progress as well as demoralize the operators who deploy the vehicles (e.g., comments [from operators] such as "another waste of money and waste of my time!"). The principal investigator should be itemizing the frequency of each component failure or cause of failure.

**Reviewer 4**

The reviewer noted that this is a very long project, 10 years and questioned whether fuel cells are the focus. The reviewer noted that truck cost and fuel cost $H_2$ should be included. The reviewer asked is Slide 8 based on range, reliability or otherwise?

The reviewer noted that this is such a long and drawn-out project. The relevance of the technology application naturally changes as the base technology evolves. It was not clear that there was a plan to include technology change from the beginning but instead to just adapt along the way.

The reviewer asked where is the comparison of the many technologies to succeed in operation on a typical route? Need to bring the segments of the project into conclusion and have a summary slide to report on it. The reviewer noted that can be a basis for comparison of next project segments.

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

**Reviewer 1**

The reviewer commented the technical progress has been excellent although the execution timeline has been longer than the original plan.

**Reviewer 2**

The reviewer stated that overall, the team did a good job putting the vehicle to the test. All vehicles met expectations and were very popular with the drivers. All this shows great potential for the technology, which is one of the goals of this project.

This reviewer wished there had been a bit more details and analysis of the powertrain. For instance, how is the fuel cell used, how is power split between the battery and the fuel cell? What are the advantages of having a higher power fuel cell system?

**Reviewer 3**

The reviewer said Slides 8 and 9 do not offer any quantitatively derived conclusions regarding how the fuel cell trucks performed. Then, the change from fuel cell trucks to a compressed natural gas (CNG) hybrid

vehicle just seems to be a scope shift that does not move toward the original intended outcomes of the project. This is not a Zero Emissions Vehicle.

**Reviewer 4**

The reviewer noted that at least a temporary portable refueling structure has been located and installed. The team completed demonstrations of six trucks and gathered performance data. A roadmap for commercialization has been compiled.

The reviewer found Slide 19 confusing--please explain why only the Kenworth ZECT is shown—is it representative of all the fuel-cell trucks or is it the best-performing of all the fuel-cell trucks?

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

**Reviewer 1**

The reviewer noted this project required a lot of coordination with the OEM who supplied the vehicles, the folks who put the hydrogen infrastructure in place, as well as the folks who did the data collection and analysis. The reviewer said job nicely done.

**Reviewer 2**

The reviewer remarked as things have moved around in this long-term project, it seems that the team has shifted accordingly. Managing those shifts is not a trivial matter.

**Reviewer 3**

The reviewer said there is widespread collaboration that crosses over at least seven contractors or organizations, including most importantly, a fleet operator—TTSI, the contractor for temporary refueling station, and the contractor for data collection which makes for a sum total of 10. This extent of collaboration and coordination is quite unusual. TTSI was an excellent choice for a fleet operator.

**Reviewer 4**

The reviewer commented the collaboration and coordination across the project team has been very effective.

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

**Reviewer 1**

The reviewer remarked that the CNG hybrid truck is not a zero emissions vehicle in any sense of the definition.

**Reviewer 2**

The reviewer is giving the benefit of the doubt to the principal investigator. Even though the principal investigator has not clearly articulated the specific goals/objectives for each of the six projects in the scope of work, he seems to be headed in the right direction and has sufficient insight into the technical barriers/obstacles that must be overcome: lack of standardized components, reliability, deploying a larger number of vehicles, and securing a reliable hydrogen fuel supply. The reviewer suggests that the principal investigator do a better job of documenting the causes for the excessive downtime in the fuel cell vehicles by itemizing the frequency of each component failure or cause of failure.

**Reviewer 3**

The proposed future research is a direct end product of the information that the project has established to date and a logical continuation for this RD&D project.

**Reviewer 4**

The reviewer said the project highlighted the key remaining challenges: lack of standardization, reliability, hydrogen fuel supply. Because several OEMs provided fuel cell trucks for the project, it would be nice to compare the pros and cons of each. This could help provide some insights in terms of which fuel cell powertrain approach works best.

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

**Reviewer 1**

The reviewer remarked the project supports DOE's effort to develop a decarbonized transportation system. The project is an avenue to put new technology into the field to help validate its viability and gain market acceptance.

**Reviewer 2**

The reviewer said this project is highly relevant and critical. First of all, the Ports of Los Angeles and Long Beach are in environmental justice communities which have been experiencing the adverse health effects of diesel for decades. Thus, this is an excellent geographic justification for this project. Second, the State of California has a mandatory goal of zero-emissions for drayage trucks by 2035. This is another excellent driver for this project. Third, there is no conceivable way for private industry to make a high-risk, high-cost investment in fuel cell engines with any certainty of a guarantee of return. Thus, a project of this nature must be federally funded.

**Reviewer 3**

The reviewer remarked this project is highly relevant to VTO's mission to advance zero emission and electrified heavy-duty vehicles.

**Reviewer 4**

The reviewer said the testing of previous fuel cell trucks is relevant. Not so sure about the CNG hybrid.

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

**Reviewer 1**

The reviewer noted this project is 10 years long, which is quite long. It is not clear why it needs to be that long. Nonetheless, the technology demonstration is an important part of testing the technology and should be very helpful to OEMs and future customers.

**Reviewer 2**

The reviewer said resources seem to be shifting as the scope has shifted but seem to be sufficient.

**Reviewer 3**

The reviewer said considering the high cost of the fuel cell engine, components, integration, and testing and the number of different vehicles, the reviewer believes that the resources appear to be sufficient.

**Reviewer 4**

The reviewer said resources for the remaining work are sufficient because the presenter did not identify 'lack of resources' as an issue affecting project performance.

**Presentation Number: elt179**
**Presentation Title: Low Cost, High-Performance, Heavy Rare-Earth-Free 3-In-1 Electric Drive Unit**
**Principal Investigator: David Crecelius, American Axle & Manufacturing**

### *Presenter*

David Crecelius, American Axle & Manufacturing

### *Reviewer Sample Size*

A total of seven reviewers evaluated this project.

### *Project Relevance and Resources*

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

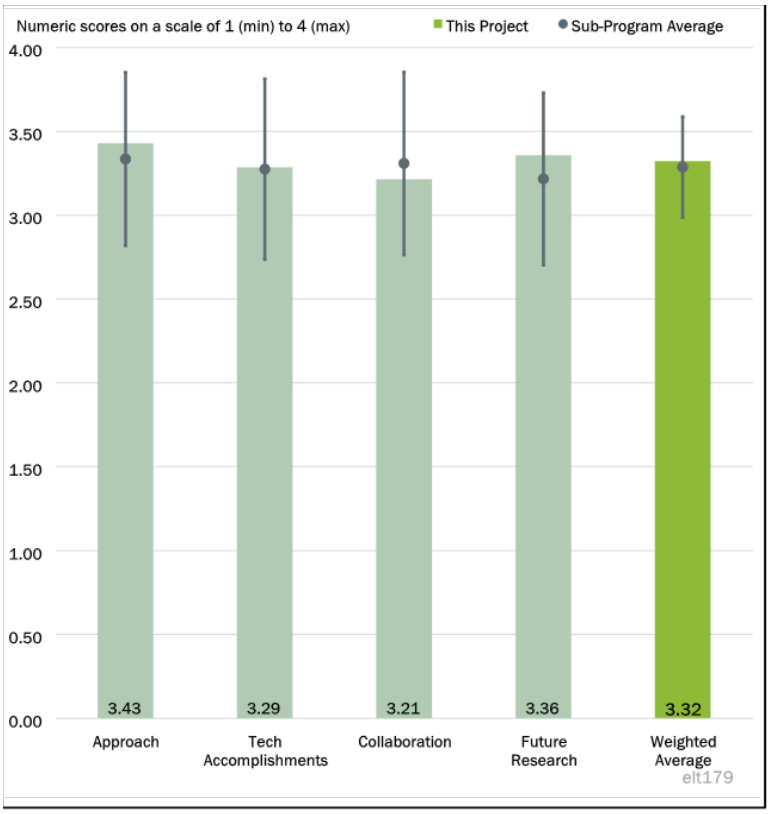


Figure 4-3 - Presentation Number: elt179 Presentation Title: Low Cost, High-Performance, Heavy Rare-Earth-Free 3-In-1 Electric Drive Unit Principal Investigator: David Crecelius, American Axle & Manufacturing

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

**Reviewer 1**

The reviewer said the project is well planned and progressing well to meet the objectives.

**Reviewer 2**

The reviewer noted that AAM's baseline technology, which is a Gen 5.0 3-In-1 electric drive unit (EDU), is illustrated in the project report along with key specifics. Budget period 1, Design Development and Technology Research, is completed and an optimized configuration of EDU is selected for fabrication in budget period 2. The reviewer noted that design (budget period 1) followed by fabrication (budget period 2) that leads to prototype for technology commercialization (budget period 3) is a logical and systematic approach for execution of this project. Also, the project's approach addresses VTO barriers, which is like effectively tying approach with relevance.

**Reviewer 3**

The reviewer commented the project is well-designed and planned. More discussion on the VTO barriers to be addressed (Slides 2, 7) would be helpful. Some specific information/data for how your project meets (or does not meet) performance, weight, and high-temperature limitations. During the Q &A, was it stated that the inverter design does not meet the 650V criteria?

**Reviewer 4**

The reviewer said this is an excellent project in which the technical barriers are addressed, and the project is well designed and planned. This reviewer is a bit confused by the presentation and description of the targets. It is not clear what exactly is included in the power density target for the electric traction drive system listed as greater than or equal to 12 kW/liter (e.g., motor + inverter, or motor+ inverter + transmission). The reviewer said some of the cooling configurations could be described more clearly in the slides.

**Reviewer 5**

The reviewer commented this project addresses various VTO technical barriers such as inverter barrier (high temperature and isolation materials for wide bandgap (WBG) switching devices), motor barrier (magnet cost and volatility), and performance barrier (performance of non-rare earth motors, and materials optimization). The project is well-defined and the timeline is reasonably planned.

**Reviewer 6**

The reviewer said the project aims to eliminate the use of heavy rare-earth (HRE) materials, increase power density and efficiency, and reduce cost. The project uses an induction motor, and the speed is 30,000, which is higher than other applications with similar power ratings.

**Reviewer 7**

The reviewer remarked well thought out plan. The plan encompasses all the appropriate evaluation criteria necessary for the technology to be commercialized.

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

**Reviewer 1**

The reviewer said excellent progress is being made on every element of the project.

**Reviewer 2**

The reviewer remarked well planned approach.

**Reviewer 3**

The reviewer said very good progress is being made on this innovative project, and the oil cooling pathway is intriguing.

**Reviewer 4**

The reviewer said technical accomplishments are good. These include the following: Stator design completed with improved slot liners and injection over molding of laminations and windings; high speed induction machine design analysis with the potential of efficiency close to permanent magnet (PM) motor; silver sintering process development for the SiC MOSFETs attachment; and optimal configuration selection for motor and drive-unit builds.

**Reviewer 5**

The reviewer remarked the project aims to trade off PM and induction motors. Induction motor speed is increased to 30,000 rpm using insulated induction motor rotor bars and optimized steel. Over-molded stator windings are used for thermal performance. Silver sintering is used for SiC devices for 650 Vdc buses. All of these aspects of the project support the project goals. The reviewer posed the following questions: What kind of rotor bar strategy is used, i.e., semi-open or closed slot, and what is the margin on mechanical design? It

would be nice to show some analysis of mechanical design. The other question is, what would be the thermal cycling impact on the induction machine's rotor and any extended-term reliability issues? How is the rotor cooled?

**Reviewer 6**

The reviewer said the PI did a very good job summarizing and discussing project accomplishments, but the progress might additionally be understood if the PI had a waterfall chart tied to Slide 7,, which showed the improvement contribution amount of each solution. The reviewer liked the collection of baseline motor data and especially the PI's discussion of the performance of the chart on Slide 20.

**Reviewer 7**

The reviewer said the stator design of the completed EDU has improved slot liners and injection over molding of laminations and windings. Over molded stator design is illustrated in the project report with designed-in features that may allow high volume manufacturing. High speed induction motor design analysis shows high power density and drive cycle efficiency found close to permanent magnet motor. Initial silver sintering process for MOSFET is developed and bond line interface found acceptable and developed IP captured.

This reviewer raised a concern: Why do the silver sintered MOSFETs have high junction temperature. This may become worse over the ambient conditions (temperature sweep -40°C to 105°C) around silver sintered MOSFETs.

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

**Reviewer 1**

The reviewer remarked the project team has demonstrated sound collaboration with Electricore (project management), Encap Technologies (stator), MacDermid Alpha (sintering), and Breuckmann eMobility (rotor).

**Reviewer 2**

The reviewer said project progress is demonstrating that each of the partners are actively participating. Given the amount of work that has been completed, it is clear that each of these activities are being well coordinated.

**Reviewer 3**

The reviewer commented good collaboration among project partners has been outlined in the project report.

**Reviewer 4**

The reviewer said continue with the collaboration with the testing and evaluation.

**Reviewer 5**

The reviewer remarked all partners were documented. It might be interesting to understand who are the customers of this motor. For example, for the PI's baseline data, where are these motors used? Would it be worthwhile to understand potential customer comments once the bench test data and costs are complete?

**Reviewer 6**

The reviewer remarked overall, there is good collaboration and engagement with suppliers. It does not appear as though Electricore is performing any technical tasks.

**Reviewer 7**

The project works with industrial supplier partners, and Electricore is the sub-recipient.

The reviewer noted working with national labs and using their expertise in specific areas can strengthen a project. Is it possible in this project?

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

**Reviewer 1**

The reviewer is highly interested in seeing actual results for performance improvements.

**Reviewer 2**

The reviewer remarked the future research outlined in the project report is supportive of tasks and milestones of budget period 2 and budget period 3.

**Reviewer 3**

The reviewer noted the presented listed barriers and challenges. Of course, it will be most interesting to understand the manufacturing/assembly/supply chain challenges during the assembly phase in stage 2. And of course if the testing shows limitations, will be good to understand the challenges of updating any needed design fixes.

**Reviewer 4**

The reviewer remarked the future research is good and well-defined.

**Reviewer 5**

The reviewer said the budget period 2 future research is well defined where a prototype will be fabricated and tested.

**Reviewer 6**

The reviewer said proposed future work involving prototype component fabrication, EDU cost estimation, build and test of the motor and EDU are all very well-motivated and the results should be interesting.

**Reviewer 7**

The reviewer noted that clear and logical next steps have been presented.

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

**Reviewer 1**

The reviewer remarked this is an important project to help determine the improvements in future cost and performance.

**Reviewer 2**

The reviewer said the project is completely relevant.

**Reviewer 3**

The reviewer commented the project is very relevant and supports VTO subprogram objectives of integrated EDUs with lower cost, higher power density, and good reliability.

**Reviewer 4**

The reviewer remarked the project supports VTO subprogram objectives of reducing dependency on heavy rare earths, while maintaining electrified drive unit performance, and reducing cost. The project team has shown a 10% cost reduction potential while maintaining PM-like efficiency.

**Reviewer 5**

The reviewer said this work is a great example of a well-defined project that focusses on risk reduction based on a complete understanding of the technology.

**Reviewer 6**

The reviewer noted that an induction motor that has performance and power density similar to a PM motor could be quite relevant to DOE objectives for electric machine technology needed for vehicle traction applications.

**Reviewer 7**

The reviewer said the project supports the overall VTO program objectives by eliminating the use of HRE materials, increasing power density and efficiency, and reducing cost. The project uses an induction motor with no permanent magnet motor. Speed is 30,000, which is higher than other applications with similar power ratings.

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

**Reviewer 1**

The reviewer said yes—resources appear to be sufficient.

**Reviewer 2**

The reviewer said resources seem to be sufficient.

**Reviewer 3**

The reviewer remarked it is difficult to judge how the assembly/build phase will proceed because there was no discussion on this point.

**Reviewer 4**

The reviewer said prototyping and testing are planned. It appears that resources are sufficient in this project.

**Reviewer 5**

The reviewer said project funding of $6.25 million over 3+ years is about right based on reviewer's prior experience with such activities.

**Reviewer 6**

The reviewer said the project has all necessary resources, technical expertise, and know-how to successfully complete this project.

**Reviewer 7**

The reviewer remarked resources are appropriate.

**Presentation Number: elt188**
**Presentation Title: Bi-Directional Wireless Power Flow for Medium-Duty, Vehicle-to-Grid Connectivity**
**Principal Investigator: Omer Onar, Oak Ridge National Laboratory**

***Presenter***

Omer Onar, ORNL

***Reviewer Sample Size***

A total of three reviewers evaluated this project.

***Project Relevance and Resources***

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

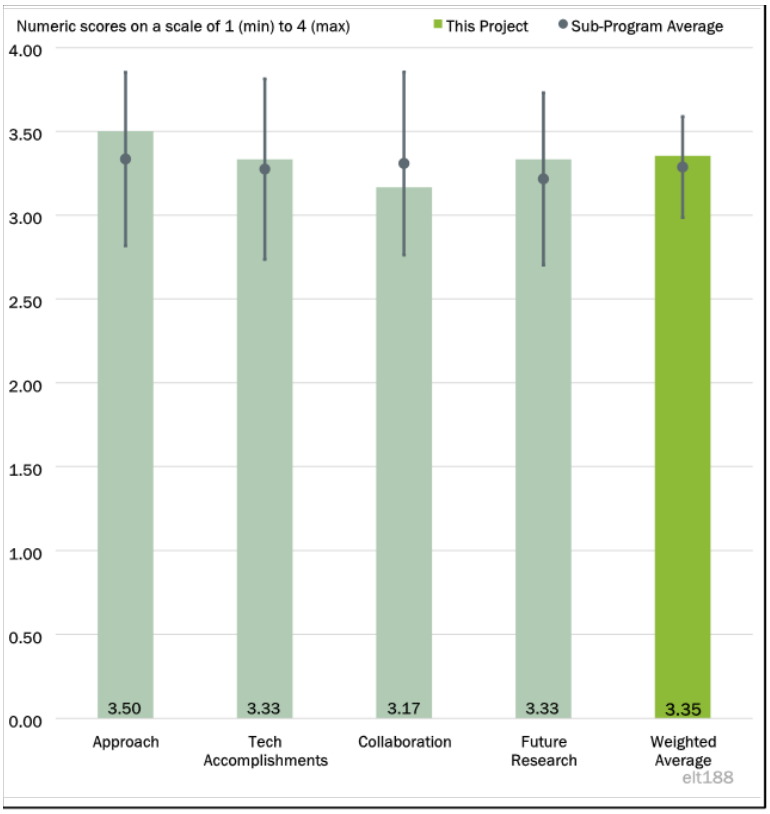


Figure 4-4 - Presentation Number: elt188 Presentation Title: Bi-Directional Wireless Power Flow for Medium-Duty, Vehicle-to-Grid Connectivity Principal Investigator: Omer Onar, Oak Ridge National Laboratory

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

**Reviewer 1**

The reviewer said good systematic approach.

**Reviewer 2**

The reviewer remarked the team is using a variety of approaches to minimize risk and enable iteration. For example, finite element analysis (FEA) allows for multiple iterations before committing to hardware and the use of battery and grid emulators enables testing of the hardware in a safe, laboratory environment. The team seems well-suited to the demonstration portion.

**Reviewer 3**

The reviewer commented the concept of the project is sound. It was a good change when 6.6 Kw to grid was abandoned in favor of 20kW. But... what is the demo duty cycle? Is it a daily bi-directional transfer? What data are you collecting regarding these transfers?

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

**Reviewer 1**

The reviewer stated the presentation seems to focus on technical accomplishments in previous years. Fiscal year 2022 accomplishments seem to be fairly incremental.

**Reviewer 2**

The reviewer noted that system design, analysis, prototype, and lab testing were all successful. Except for the 1-year COVID-19 pause, this project has completed tasks within original allotted time frames. Nice job.

The reviewer said that if CALSTART is doing a business case, why is it not being reported.

**Reviewer 3**

The team has made excellent progress in all aspects of the project after recovering from COVID-19-related delays. The team has exceeded their targeted power handling in the vehicle-to-grid (V2G) application. The PIs have identified the challenges associated with light load and are working to improve efficiency, which is already very good for this stage of the project.

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

**Reviewer 1**

The reviewer remarked there seems to be good level of collaboration among partners.

**Reviewer 2**

The reviewer said it is clear that ORNL and UPS are tightly coupled with great collaboration and coordination. The other team members are also clearly contributing and engaged.

**Reviewer 3**

The reviewer said the project lead entity did not participate in the presentation, and no explanation was given.

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

**Reviewer 1**

The reviewer said as this project transitions to a full deployment, the team has made appropriate modifications to the equipment that will enable effective integration with the target facility's workflow and infrastructure. At the end of the project, the equipment will reach a higher technology readiness level than originally targeted.

**Reviewer 2**

The reviewer remarked the system design build and testing was very well presented. Until the question was asked, at no time was any information given as to what the future work, namely the demonstration phase, was intended to accomplish and why it was important. Bi-directional wireless power transfer is only a 'nice to have' unless it is understood how UPS will use this feature. It is not for emergencies as UPS facilities have back-up power systems. The reviewer asked how will the benefits of having it be measured in a demonstration. The speaker said this could be a separate project but because the project says it includes a 6-month demonstration, the reviewer respectfully disagrees with that statement. Again, the project lead should have provided a slide to describe what the future work was intended to accomplish.

**Reviewer 3**

The reviewer said that verification testing in the actual vehicle is needed.

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

**Reviewer 1**

The reviewer said timely topic that can help meet the DOE objectives.

**Reviewer 2**

The reviewer said it is relevant to the VTO goals.

**Reviewer 3**

The reviewer commented this project provides bidirectional capability to wireless charging infrastructure to enable both smart charging and V2G applications. For large truck depots, even with relatively low-power operation, the aggregate impact can be substantial.

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

**Reviewer 1**

The reviewer said resources are sufficient based on project scope.

**Reviewer 2**

The reviewer remarked timely completion of tasks indicates that resources are 'right sized.'

**Reviewer 3**

The reviewer said the team seems to be well-positioned to deploy the prototypes and gather appropriate field data.

**Presentation Number: elt197**
**Presentation Title: High Power and Dynamic Wireless Charging of Electric Vehicles**
**Principal Investigator: Veda Galigekere, Oak Ridge National Laboratory**

***Presenter***

Veda Galigekere, ORNL

***Reviewer Sample Size***

A total of five reviewers evaluated this project.

***Project Relevance and Resources***

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

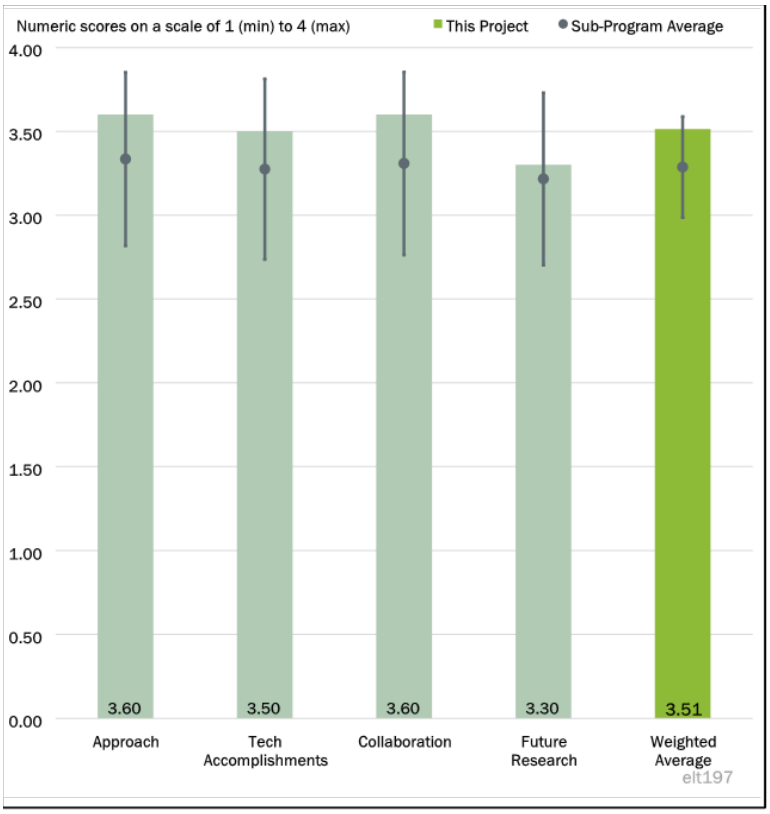


Figure 4-5 - Presentation Number: elt197 Presentation Title: High Power and Dynamic Wireless Charging of Electric Vehicles Principal Investigator: Veda Galigekere, Oak Ridge National Laboratory

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

**Reviewer 1**

The reviewer said the project was extended due to COVID-19-related delays. It is on schedule to be completed 6 months later than planned. Lead times for parts are all longer so the project demonstration is taking longer. That seems reasonable. The studies and design work were followed by hardware development then lab validation ending project with real world demonstration. Great approach to the project and barriers that are being addressed. The real-world demonstration will take place at the American Center for Mobility (ACM), which is set up to take data in all seasons. The ACM should be able to test real world conditions such as rain and salt's impact on the charging equipment and processes.

**Reviewer 2**

The reviewer said very good systematic approach.

**Reviewer 3**

The reviewer remarked this work is well planned. Technical milestones are properly defined and are measurable. However, the project is delayed from original schedule.

**Reviewer 4**

The reviewer said the work done so far has been great—especially with reference to light-duty (LD) vehicles. The main concern is that with LD vehicles, range anxiety is less problematic especially when compared to

medium-duty (MD) and heavy-duty (HD) vehicles (Class 3, 4, 5, and above), because the range takes a huge hit when towing a trailer. For LD vehicles in most cases, there could possibly be sufficient battery capacity to alleviate range anxiety, but it is quite otherwise with MD and HD vehicles with high gross combined weight rating. It would help if there is a stronger focus on these scenarios, and what requirements they may bring to the design of the dynamic wireless power transfer (DWPT) system.

Another concern is the damage that the system can sustain during winter, when the repeated freeze-thaw cycles cause huge potholes to show up. How would maintenance of these be managed? And if vehicles are designed with the assumption that DWPT would always be available, what happens when the system is down due to potholes or any other reason. Most OEMs may have to design their vehicles to handle the situation where DWPT may be temporarily unavailable, which may negate the benefit by resulting in large batteries being required.

**Reviewer 5**

The reviewer remarked the technical barriers with electronics (power and efficiency), shielding, and data acquisition have been clearly defined and addressed. There is little doubt that the team will have a system meeting the technical goals established at project inception.

The reviewer said discussion of electromagnetic (EM) shielding and effects on humans as well as cost should receive much greater attention. The team did not identify standards for acceptable electromagnetic (EM) exposure. Additionally, the cost/benefit was optimized for a DWPT enabled infrastructure, but not compared with alternative technical solutions. The cost of electrifying up to 16% of long-distance highway routes must be addressed to undergird the credibility of the project.

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

**Reviewer 1**

The reviewer said the team has achieved significant technical milestones and made excellent progress.

**Reviewer 2**

The reviewer commented the PI described lots of accomplishments. The team worked their way up from smaller to larger more complicated aspects of the project. The team was able to look at the vehicle and confirm there were no hot spots. Additionally, the team address potential hot spots with aluminum as a means of risk mitigation. The laboratory demonstration should be conducted at 20 mph. Thus far the team has demonstration charging in the lab at up to 10 mph. There are no standards for dynamic charging so the PI and his team have targeted emissions compliance at the edge of the driving lane and in the vehicle. It is appreciated that the team created the boundaries needed to move forward in the analysis and project in the absence of data.

**Reviewer 3**

The reviewer stated very good progress and risk mitigation

**Reviewer 4**

The reviewer said this is a little behind schedule due to COVID-19, but excellent progress overall. The results of the testing at ACM should be interesting.

**Reviewer 5**

The reviewer remarked the project has fallen somewhat behind a rather aggressive schedule. Dynamic validations and the data acquisition challenges associated with them remain to be accomplished. It is not clear

where the project is with respect to budget. It is showing 100% complete on the Overview slide, inferring that the budget has been exhausted, with some significant work remaining.

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

**Reviewer 1**

The reviewer said very good collaboration effort between a national lab, OEMs, and universities.

**Reviewer 2**

The reviewer commented excellent collaboration and well-defined roles among partners.

**Reviewer 3**

The reviewer remarked the project team has a good group of lab staff, OEMs, and academia. While no transportation agencies or utilities are part of the team, the team is in communication with Florida's and Georgia's Department of Transportation as well as TVA and other utilities. The PI acknowledged that they have not started discussions with Federal Highways and should be in communication with them. While the PI explained that an electric vehicle supply equipment (EVSE) member of the team had pulled out of the project. These things happen. It would have been nice to see them engaging with some sort of manufacturing or installation perspective to understand what it would take to create and install this solution in the real world. Perhaps that is a follow-on project.

**Reviewer 4**

The reviewer said the team has correctly identified areas for technical and non-technical collaboration. Next stage will require close partnership to deliver field demonstrations.

**Reviewer 5**

The reviewer commented the team has joined the appropriate technical talent from multiple national laboratories. Excellent collaboration and coordination are evident in the hardware development and testing to date. The reviewer suggested that the team expand to include safety and cost analysis resources to examine non-technical barriers to project feasibility.

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

**Reviewer 1**

The reviewer pointed out that real life testing is critical for proving the concept.

**Reviewer 2**

The reviewer remarked the project team has describe the pending demonstration and the data planned for that demonstration. Deep dive discussions will take place under the Electric Vehicles at Scale (EVs@Scale) Consortium.

**Reviewer 3**

The reviewer referred to a prior question, and believes there are still many issues that need to be addressed. As previously mentioned, an OEM would design a vehicle that would not lose functionality based on availability or non-availability of the DWPT. Customers may not be accepting of a vehicle that provides severely reduced functionality when the DWPT charging network is down for whatever reason. This would require over-design of the energy storage system.

The reviewer noted that another scenario that should be investigated is the requirements and response of the system during extreme weather events, such as Hurricane Rita. The reviewer hadseveral friends who had to get out of Houston, and were stuck on roads with bumper to bumper traffic for hours. What requirements do such events impose on the design of the DWPT system?

**Reviewer 4**

The reviewer said the project is extremely focused on demonstrating technical feasibility. This appears to be without recognition of non-technical issues like safety and cost. Future work continues to be only technically focused. A more detailed look at EM exposure and system cost should be a part of future work.

**Reviewer 5**

The reviewer commented proposed future research should be made more comprehensive.

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

**Reviewer 1**

The reviewer said the project is very much relevant to VTO's Electrification and Energy Efficient Mobility Systems programs.

**Reviewer 2**

The reviewer remarked timely topic that can help meet the DOE objectives.

**Reviewer 3**

The reviewer remarked dynamic wireless charging enables high power and interoperable charging. If the technology becomes widespread it could also bring down the size of the batteries in vehicles and the electric vehicle's (EV) cost. These are important factors in electrifying fleets. The reviewer recognizes that those costs would be distributed to the grid and road infrastructure, but believed that would be okay.

**Reviewer 4**

The reviewer said this is a very relevant project for achieving wide adoption of EVs and electrical infrastructure support.

**Reviewer 5**

Again, the project must address safety and cost if it is to have credible relevance. The reviewer specified the project should look at a broad range of applications to determine where the DWPT can be relevant from a cost perspective and can assure public safety in a litigious environment.

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

**Reviewer 1**

The reviewer said at this point the resources appear to be sufficient.

**Reviewer 2**

The reviewer remarked resources are sufficient based on proposed scope

**Reviewer 3**

The reviewer said the resources for the project seemed sufficient.

**Reviewer 4**

The reviewer said the project required additional support to complete next steps in time.

**Reviewer 5**

The reviewer said technical resources across a broad spectrum of capabilities have been applied to the project. Non-technical aspects of the project (safety and cost) should receive the same level of resource commitment.

**Presentation Number: elt208**
**Presentation Title: Highly Integrated Power Module**
**Principal Investigator: Lincoln Xue, Oak Ridge National Laboratory**

***Presenter***

Lincoln Xue, ORNL

***Reviewer Sample Size***

A total of five reviewers evaluated this project.

***Project Relevance and Resources***

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

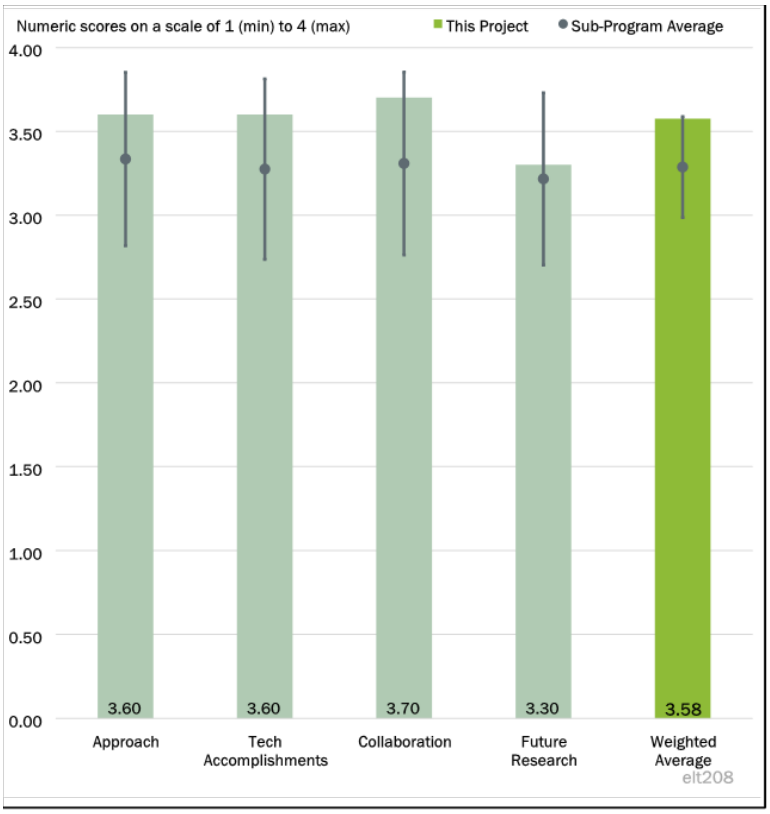


Figure 4-6 - Presentation Number: elt208 Presentation Title: Highly Integrated Power Module Principal Investigator: Lincoln Xue, Oak Ridge National Laboratory

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

**Reviewer 1**

The reviewer said the project develops new cooling method for power semiconductor devices. Genetic algorithms are used to optimize the heat sink topology. Simulation and test results have demonstrated significant thermal performance improvement. The reviewer said the project is well designed and the timeline is reasonably planned.

**Reviewer 2**

The reviewer said the project aims (design and cooling improvements) are appropriate to the task of shrinking the power module to meet the overall 100kW/L inverter requirement.

**Reviewer 3**

The reviewer remarked this project is a comprehensive approach for addressing the technical barriers for high-density packaging of EV drives.

**Reviewer 4**

The reviewer commented the technical approach of the research is excellent; however, the reviewer wanted to see some identification of reliability and cost versus current industry standard. Perhaps a chart or table that summarizes and compares temperature/power density/cost to other approaches. The team states that reliability of current power modules is difficult to obtain, but perhaps you can assign this task to one of your partners,

along with a cost identification procedure. The reviewer asked will the reliability target be a combination of thermal cycles and vibration loading? How will the final test be performed and/or simulated?

**Reviewer 5**

The reviewer remarked a low-cost and high-power density SiC inverter that has 15 years and 300,000 mile life-time is needed for wide adoption of WBG technology in vehicle traction applications. This project attempts to address DOE's Electrification program's (ELT) 2025 targets for cost, power-density, reliability, and efficiency.

This reviewer has huge concern with selection of 2 kV breakdown voltage between electrical live parts/sections and touch-safe portion (heat-sink) in the highly integrated power module. Performers must raise this breakdown voltage to 5 kV for 800V direct current (DC) bus inverter.

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

**Reviewer 1**

The reviewer remarked the team has completed the quarter 1 and quarter 2 milestones for fiscal year (FY) 2022. Results have shown significant thermal performance improvement. Other milestones are on track. Overall, the team is making outstanding progress.

**Reviewer 2**

The reviewer remarked electrical (gate driver and power circuit) and thermal (heat sink, heat sink, and thermal interfaces) designs and performances (SiC die temperature rise for jet impingement method) thereof for a highly integrated SiC power module are completed and the rest of technical progress is on track.

**Reviewer 3**

The reviewer said the team has shown excellent results so far. The cooling performance achieved is encouraging but raised a few questions: Why was 1.6 lpm flow rate a constraint for the indirect-cooling system when the jet-impingement system was evaluated at rates up to 3.2lpm? Have you considered the manufacturability of the optimized heat sink? It looks non-uniform in shape

**Reviewer 4**

The reviewer said very good explanation of accomplishments. The reviewer wished that the team would have had one final slide that tabulated the results.

**Reviewer 5**

The reviewer said the team has made significant technical progress on all parts of the technical approach: gate-driver integration, substrate materials, cooling designs, and experimental validations. This reviewer urges the team to construct prototypes of the integrated power module and demonstrate them in a 100 kW/L power density inverter.

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

**Reviewer 1**

The reviewer said great collaboration between university, government lab, and industry to achieve the project result. Each sector has made a key contribution and lent specific expertise to the project. The involvement of DuPont for their direct bonded copper material is notable.

**Reviewer 2**

The reviewer remarked the team's collaboration partners have extensive R&D expertise covering all parts of the proposed work.

**Reviewer 3**

The reviewer said all project partners are working to successfully complete project tasks and have timely delivery of milestones

**Reviewer 4**

The reviewer commented collaboration between team members is well coordinated.

**Reviewer 5**

The reviewer was unclear how important each of the partner deliveries are to the project outcome.

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

**Reviewer 1**

The reviewer remarked the proposed future research is clear and appropriate. The likelihood for the team to achieve its target is high based on the results presented for the new cooling design.

**Reviewer 2**

The reviewer remarked next steps are clearly outlined and seem to be manageable given the progress to date.

**Reviewer 3**

The reviewer said proposed future work is well planned, but challenging. A key challenge will be from ensuring a high enough yield in module packaging and assembly.

**Reviewer 4**

The reviewer said necessary tasks and plans are described in project presentation document.

**Reviewer 5**

The reviewer said the discussion of remaining barriers to be addressed was limited. The reviewer thought this slide should have more content/discussion, especially around potential problems that might arise in prototyping, costing, or testing.

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

**Reviewer 1**

The reviewer commented improving power electronics capability and performance is key to enabling electrification. The research may lead to higher performance, lower cost, more compact systems that can be used in EVs.

**Reviewer 2**

The reviewer noted that successes of this project are necessary for DOE VTO to meet its 2025 EV drive targets.

**Reviewer 3**

The reviewer said completely relevant.

**Reviewer 4**

The reviewer remarked yes, a high power density SiC inverter supports VTO's 2025 targets

**Reviewer 5**

The reviewer remarked the project supports VTO subprogram objectives by developing new cooling methods for power semiconductors to achieve higher power density for power converters of vehicles.

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

**Reviewer 1**

The reviewer noted that researchers did not indicate any areas where they are in need of additional resources to meet the project requirements.

**Reviewer 2**

The reviewer said resources are sufficient.

**Reviewer 3**

The reviewer said the project has the necessary resources and plan to execute project tasks and meet milestones.

**Reviewer 4**

The reviewer remarked the team has excellent resources to achieve the stated milestones.

**Reviewer 5**

The reviewer commented it was somewhat difficult to judge this without more information about the budget breakdown and work of the partners.

**Presentation Number: elt209**
**Presentation Title: High-Voltage, High-Power Density Traction-Drive Inverter**
**Principal Investigator: Gui-Jia Su, Oak Ridge National Laboratory**

***Presenter***

Gui-Jia Su, ORNL

***Reviewer Sample Size***

A total of five reviewers evaluated this project.

***Project Relevance and Resources***

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

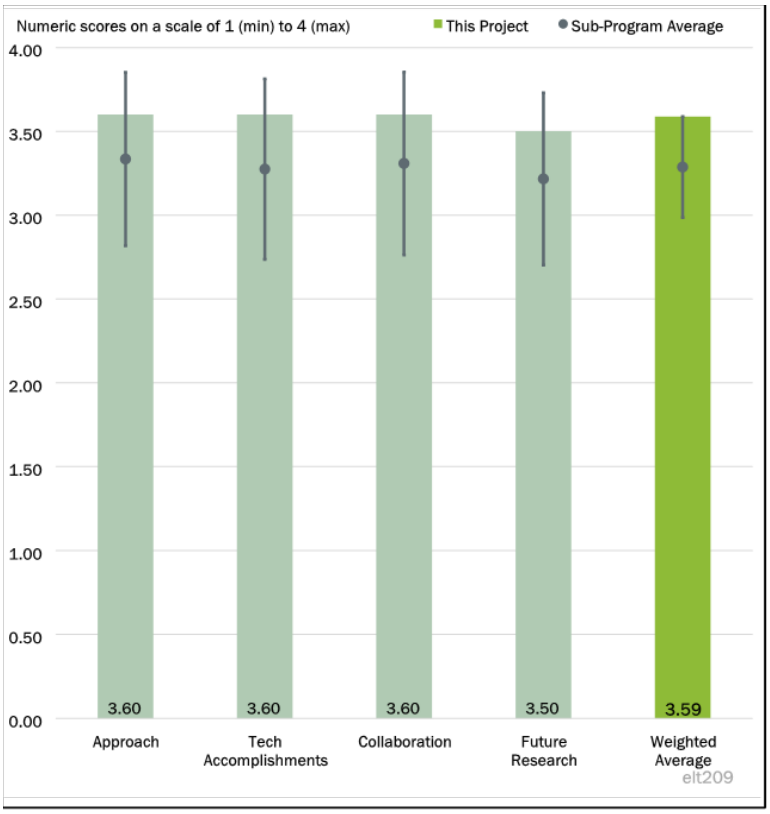


Figure 4-7 - Presentation Number: elt209 Presentation Title: High-Voltage, High-Power Density Traction-Drive Inverter Principal Investigator: Gui-Jia Su, Oak Ridge National Laboratory

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

**Reviewer 1**

The reviewer said the project approach tackles a number of issues that would enable the project goal: Interesting inverter topology and control applied to reduce capacitor size for smaller package; use of SiC devices for higher efficiency (lower heat generation) and system cooling. The results look promising.

**Reviewer 2**

The reviewer said the team has a clear, well-thought approach for the project.

**Reviewer 3**

The reviewer said the team uses the interleaved switches, optimized bus bar, and capacitor design to increase the power density of a vehicle power converter. The team demonstrated a 100-kW prototype. The results show the design meets the power density target 100 kW/L. The reviewer suggested the team show the cost analysis next year.

**Reviewer 4**

The reviewer remarked a very good overall approach of the various activities needed to deliver the overall power system density goal. However, there was too little discussion supporting the reliability and cost goals for a typical application. Also, a discussion on how the overall system performs was lacking. The approach of each activity was well defined and discussed, but how the solutions work and deliver the overall system performance needs further documentation.

**Reviewer 5**

The reviewer commented the team has used a systematic and step by step approach to resolve technical barriers to achieve power-dense (100 kW/L) low cost ($2.7/kW) high efficiency (greater than 97%) reliable (300,000 miles endurance or 15 years life). However, this reviewer has severe doubt that project team will ever meet cost target of $2.7/kW.

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

**Reviewer 1**

The reviewer said outstanding progress. Keep up the great work.

**Reviewer 2**

The reviewer said the team has built a 100-kW inverter prototype and got preliminary test results to meet the power density target. The team plans to fully characterize the 100-kW prototype by the end of quarter 3 of FY 2022. The reviewer considers this outstanding progress and suggests the team show comprehensive test results of this 100-kW prototype in next year's review.

**Reviewer 3**

The reviewer noted the team has developed and tested a 100kW inverter. The 200kW unit design is a little short of the 100kW/L target but impressive nevertheless. We look forward to seeing how it performs. It would be useful for the reviewers to compare the design to an industry benchmark design.

**Reviewer 4**

The reviewer remarked good supporting data, charts, and pictures to support the accomplishment discussion. It would be helpful at the end of the accomplishment discussion to show a waterfall chart that summarizes the performance contribution of each component and sums up the performance improvement expected with the inverter system.

**Reviewer 5**

The reviewer said progress is quite good. In Slide 14 of the project report, data shown on left side of slide including junction temperature rise do not match with data shown in Table on right side of this slide. Symmetrical space vector pulse width modulation (SVPWM) technique is indicating lower junction temperature in the far left-side illustration while table on the far right shows that bus-clamp SVPWM renders lower junction temperature. The reviewer requested the project team to clarify this discrepancy.

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

**Reviewer 1**

The reviewer remarked collaboration between team members is well coordinated.

**Reviewer 2**

The reviewer said all entities/partners in the project team are collaborating as expected of them.

**Reviewer 3**

The reviewer noted excellent collaboration on key tasks across a number of organizations. The accomplishments to date would be difficult without close communication and collaboration.

**Reviewer 4**

The reviewer said a great group of collaborators.

**Reviewer 5**

The reviewer was not entirely clear how the university input is being used. Is Virginia Tech only responsible for 100kW modules and the University of Arkansas only responsible for 200KW modules?

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

**Reviewer 1**

The reviewer said next steps are important follow-ons to the work completed. The 200kW inverter in hardware should be very interesting and challenging (to reduce the volume by 0.6L!).

**Reviewer 2**

The reviewer said excellent plan, but the future work is challenging.

**Reviewer 3**

The reviewer said well done listing challenges that have been uncovered and being open to tackle new ones. However, the reviewer would have appreciated seeing more documentation on this slide.

**Reviewer 4**

The reviewer remarked the plan is described and will lead to a successful project outcome. Technology commercialization is not clear and probably there is no possibility to commercialize the technology that is under development.

**Reviewer 5**

The proposed future research is clear and timeline is reasonable. The likelihood of achieving the targets is high.

The reviewer suggests the team show comprehensive test results of 100-kW and 200-kW prototype in next year's review and add cost analysis.

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

**Reviewer 1**

The reviewer said the project supports the VTO subprogram objectives by using interleaved switches, optimizing bus-bus design, and reducing the size of passive components to increase the power density of vehicle power converters.

**Reviewer 2**

The reviewer said the work supports advancement in component design for electrification. More compact, efficient power electronics enables better EV vehicle design for usable driving range.

**Reviewer 3**

The reviewer said yes.

**Reviewer 4**

The reviewer said highly relevant.

**Reviewer 5**

The reviewer noted the project attempts to meet DOE's ELT 2025 target except the cost target of $2.7/kW, which seems not possible to achieve.

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

**Reviewer 1**

The reviewer said resources appear sufficient. One supposes more resources would get the job done faster but progress is excellent with the current funding.

**Reviewer 2**

The reviewer remarked resources are sufficient.

**Reviewer 3**

The reviewer said the team has excellent resources to achieve the stated milestones in time.

**Reviewer 4**

The reviewer commented the project team has all necessary resources, except supply chain issues may be not be adequately addressed by project team, which may cause unnecessary delay in completion of project tasks and delivery of milestones.

**Reviewer 5**

The reviewer remarked difficult to judge this because the total project budget was not shared. However, no issues were highlighted by the speaker.

**Presentation Number: elt210**
**Presentation Title: Development of Next-Generation Vertical Gallium-Nitride Devices for High-Power Density Electric Drivetrain**
**Principal Investigator: Andrew Binder, Sandia National Laboratories**

***Presenter***

Andrew Binder, SNL

***Reviewer Sample Size***

A total of four reviewers evaluated this project.

***Project Relevance and Resources***

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

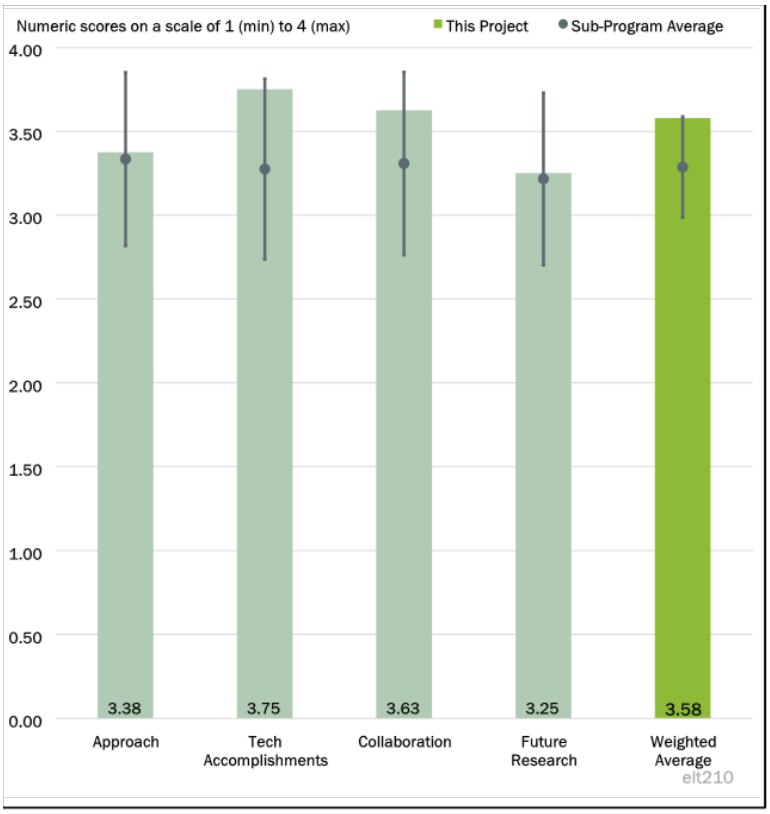


Figure 4-8 - Presentation Number: elt210 Presentation Title: Development of Next-Generation Vertical Gallium-Nitride Devices for High-Power Density Electric Drivetrain Principal Investigator: Andrew Binder, Sandia National Laboratories

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

**Reviewer 1**

The reviewer said the project has made outstanding progress.

**Reviewer 2**

The reviewer noted this was descried in the Slide 6 of project report. The project team is taking a three-steps approach, which is step-by-step problem solving to start with the easier one first to be solved.

**Reviewer 3**

The reviewer said the project is tightly focused on the basic mechanical challenges of building gallium nitride (GaN) devices. The project provides fundamental techniques that can be used to make GaN a reality for industry use. A weakness is lack of an industry partner that would build such devices. I think that would really unlock the power of this research.

**Reviewer 4**

The reviewer was not entirely clear how the GaN development is tested to prove it is a viable solution for an inverter design. The actual work plan for the coming year and to project completion was not discussed enough. This topic needs more discussion but most of the time was taken by discussion of accomplishments.

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

**Reviewer 1**

The reviewer noted that surface induced leakage current from passivation is a difficult problem for GaN-based power devices and it seems like the project has solved this issue along with tracking on many challenging issues related to the development of vertical GaN devices (MOSFET and junction barrier Schottky [JBS] diode).

**Reviewer 2**

The reviewer said the team has achieved all milestones.

**Reviewer 3**

The reviewer remarked technical progress in demonstrating fundamental performance capability with the techniques developed in the project is impressive.

**Reviewer 4**

The reviewer appreciates the many boxed notes on each accomplishment slide.

As expected, there are many accomplishment slides highlighting a variety of the design aspects. The reviewer said the team needs an accomplishment summary slide at the end of the discussion.

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

**Reviewer 1F**

The reviewer remarked the team has correctly identified all relevant parties.

**Reviewer 2**

The reviewer appreciated the description of each partner's work on the collaboration slide.

**Reviewer 3**

The reviewer said collaboration is excellent but as mentioned in a prior question, it seems the team needs a device maker that is working on GaN to really be able to exploit your techniques and indicate where improvements can be made.

**Reviewer 4**

The reviewer said that the project team led by Sandia National Laboratories (SNL) has many entities in this collaborative project and collaborative activities as per expectation in finding technical solution for the 1200 V GaN devices (MOSFET and JBS diode).

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

**Reviewer 1**

The reviewer said future work described is appropriate follow-up to the progress made so far.

**Reviewer 2**

The reviewer remarked well done.

**Reviewer 3**

The reviewer remarked as expected, GaN-based JBS, MOSFET, and circuit system level research is outlined in the project report and orally described during the presentation in AMR.

**Reviewer 4**

The reviewer said proposed future research is logical and aligned with project objectives.

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

**Reviewer 1**

The reviewer commented the project is highly relevant to making GaN an everyday option for electrification. GaN will allow more robust EV performance and increase efficiency by reducing cooling requirements.

**Reviewer 2**

The reviewer remarked a vertical GaN MOSFET is needed, as for an 800V DC bus GaN inverter, there exists no WBG device. Therefore, power conversion systems' integrators are left with the option of using either a SiC 2-level inverter or a 3-level GaN inverter. A 2-level inverter is quite simplified and reliable too compared to the 3-level GaN inverter. Therefore, a vertical GaN MOSFET with 1200V blocking is needed. Also, per the reviewer, a GaN MOSFET will fulfill DOE ELT 2025's targets of the power-density (100 kW/L) and probably cost ($2.7/kW) too.

**Reviewer 3**

The reviewer said the project is aligned with VTO objectives on electrification.

**Reviewer 4**

The reviewer would like to see a summary of the breakdown of requirements for each solution topic and the status to goal.

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

**Reviewer 1**

The reviewer said progress is good. Resources appear adequate.

**Reviewer 2**

The reviewer said the project has sufficient resources.

**Reviewer 3**

The reviewer said although the project team has necessary resources, the team must have its eye on any supply chain related issue, particularly system level (power conversion circuit) insertion of the 1200V rated GaN MOSFET.

**Reviewer 4**

The reviewer remarked difficult to judge because the total project cost is not listed. Also, is the project operating with a no cost extension? In that case, are the partners on-board for delivering the work? Will the team be able to finish the project?

**Presentation Number: elt215**
**Presentation Title: Permanent Magnets Without Critical Rare Earths to Enable Electric Drive Motors with Exceptional Power Density**
**Principal Investigator: Iver Anderson, Ames Laboratory**

***Presenter***

Iver Anderson, Ames Laboratory

***Reviewer Sample Size***

A total of three reviewers evaluated this project.

***Project Relevance and Resources***

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

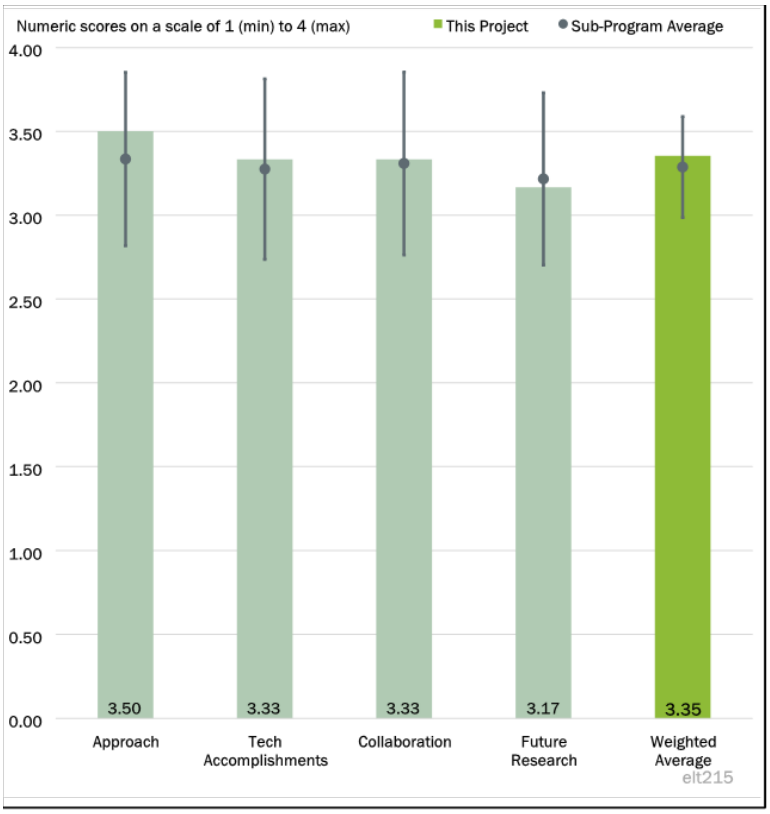


Figure 4-9 - Presentation Number: elt215 Presentation Title: Permanent Magnets Without Critical Rare Earths to Enable Electric Drive Motors with Exceptional Power Density Principal Investigator: Iver Anderson, Ames Laboratory

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

**Reviewer 1**

The reviewer remarked the project addresses a critical technology gap in the supply chain for electric vehicles. Future increases in domestic EV manufacturing require higher performance magnetic materials with a resilient supply chain. The approach to solving the technical barriers is rigorous and well planned. Deviations from the original plan to use a jet mill at a corporate partner was not possible due to pandemic related delays, but the team has effectively pivoted to other approaches.

**Reviewer 2**

The reviewer noted the project aims to reduce PM costs and eliminate use of HREs, which are scarce and costly. The project aims to create a better magnet using ultrafine grain technology to improve the motor design. The goal is to achieve cost-effectiveness and high efficiency. The project has a step-by-step process to create this new magnet using material science technology. The timeline is well planned.

**Reviewer 3**

The reviewer said the projected improvement in coercivity compared to commercially available HRE-free magnets is encouraging. The reviewer was not clear if the work on soft magnetic materials is continuing or not.

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

**Reviewer 1**

The reviewer said the quantification of motor performance based on achieved/projected properties should be included.

**Reviewer 2**

The reviewer remarked the approach to achieving improved magnetic properties has achieved good progress at the lab scale, and further progress depends on demonstration with production scale equipment.

**Reviewer 3**

The reviewer noted the projects aims to create impact using ultrafine grain magnets to reduce PM motor eddy current losses and improve PM motor power density. Reducing cost and increasing efficiency at elevated temperatures are targeted. If successful, this project enables designs with less PM cooling. The reviewer said the team developed an NFR passivation apparatus and carried out a trial run. The project established a relationship among passivation parameters, power oxidations, etc.

The reviewer said it has been shown that an ultrafine-grain HRE-free rare Earth (RE)-PM can raise coercivity and stabilize high-temperature properties. Feedstock and commercial strip cast HD are successfully used. The research concluded that 5% Pr-Cu is a good choice.

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

**Reviewer 1**

The reviewer noted this project collaborates well with ORNL for motor design advances, NREL mechanical and thermal aspects, and SNL for coordination with universities.

**Reviewer 2**

The reviewer remarked the level and details of collaboration are not very clear.

**Reviewer 3**

The reviewer said collaboration between Ames National Laboratory, ORNL, NREL and SNL was mentioned but little data was presented.

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

**Reviewer 1**

The reviewer commented the plan includes access to a multi-jet milling process for alternative passivation of ultrafine grains. Plans also include optimizing the chemistry of the magnet and better understanding mechanical properties for motor use.

**Reviewer 2**

The reviewer said the plan seems satisfactory.

**Reviewer 3**

The reviewer remarked proposed future research to use multi-jet milling will be very important and critical to the success of the project.

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

**Reviewer 1**

The reviewer said reduction and/or elimination of RE material is a strategic goal that is consistent with DOE targets.

**Reviewer 2**

The reviewer said yes, the program is relevant to the DOE Electrification subprogram. Meeting the goals on the EV roadmap will require improvements to magnetic material performance and a resilient supply chain.

**Reviewer 3**

The reviewer remarked yes, the electrification of vehicles requires traction motors that are low-cost and efficient. This project is relevant to getting rid of HRE and developing alternative technology for traction motors of all kinds of electric vehicles.

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

**Reviewer 1**

The reviewer said resources are sufficient based on the proposed scope.

**Reviewer 2**

The reviewer said it seems like the only issue is the multi-jet milling capability. Pandemic and other supply chain issues appear to limit the access to multi-jet technology. Other than that, it seems like progress is happening as planned.

**Reviewer 3**

The reviewer remarked the team has sufficient resources to carry out the program objectives. However, completing the program will require access to a multi-jet mill that is not available within Ames National Laboratory.

**Presentation Number: elt216**
**Presentation Title: Isotropic, Bottom-Up Soft Magnetic Composites for Rotating Machines**
**Principal Investigator: Todd Monson, Sandia National Laboratories**

***Presenter***

Todd Monson, SNL

***Reviewer Sample Size***

A total of four reviewers evaluated this project.

***Project Relevance and Resources***

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

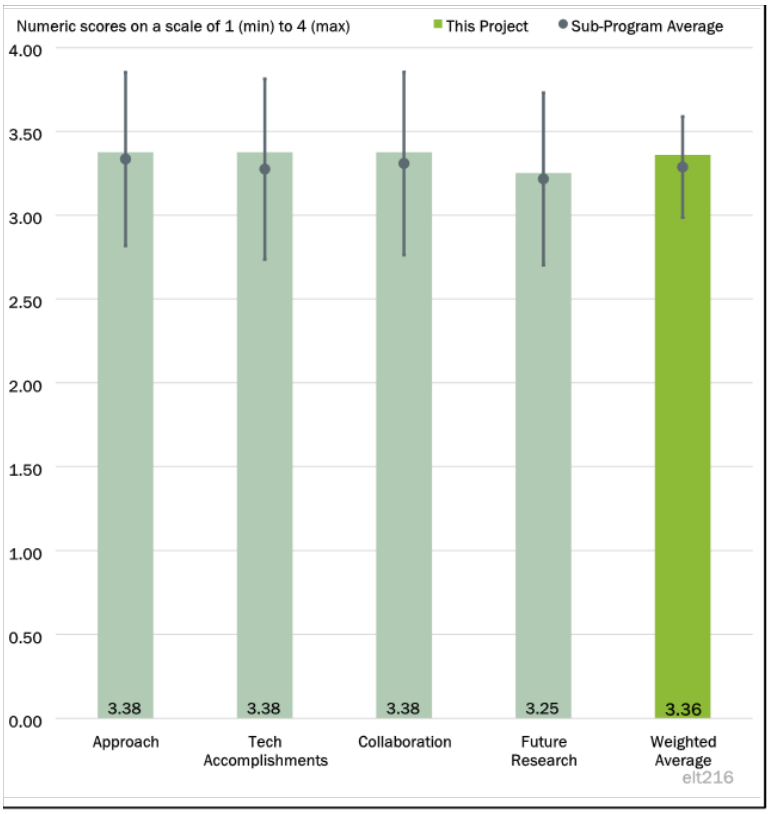


Figure 4-10 - Presentation Number: elt216 Presentation Title: Isotropic, Bottom-Up Soft Magnetic Composites for Rotating Machines Principal Investigator: Todd Monson, Sandia National Laboratories

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

**Reviewer 1**

The reviewer detailed this project aims to develop soft magnetic materials for electric motors. This material can be significant for homopolar and axial machine designs where PMs are not used. Hence, this project is timely to eliminate RE elements that are used in PMs.

The proposal mainly focuses on iron nitride/epoxy composites to create soft magnetic material. The project focuses on fabricating, curing, and polishing these soft magnetic materials using iron nitride with different percentages for volume.

**Reviewer 2**

The reviewer remarked the project is well planned and is methodically addressing the technical barriers needed to demonstrate the ability of iron-nitride powder filled epoxy composites to perform as soft magnetic motor components.

**Reviewer 3**

The reviewer said the team developed a new soft magnetic composite material that uses cheap and abundant elements. The team targets to achieve 1.89 T saturation polarization. The most updated work has achieved 1.19 T and the team plans to further improve the saturation level. The mechanical strengths of the magnetic composite material are significantly lower compared to those of silicon steel. The reviewer's suggestion is not to use the magnetic composite material to build the machine rotor. If the team can achieve 1.89 T saturation

polarization in the coming years, using this material to build machine stators to improve performance is still a success.

**Reviewer 4**

The reviewer said the project should provide a comparison of the projected properties to other lamination materials.

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

**Reviewer 1**

The reviewer said the team has made excellent progress towards reaching the goals of the project. The technology tasks are appropriate and the rate of progress has been to plan.

**Reviewer 2**

The reviewer commented the project analyzed and tested the mechanical strength of iron nitride and epoxy. It has been found that the volume % loading of iron nitride can be more than 75%. This technology can also be used for inductors and achieve low loss soft magnetic material alternative instead of laminated steels and ferrites. The goal of the project is to achieve high magnetization levels to be applicable for both motor and inductor designs.

**Reviewer 3**

The reviewer noted the team plans to finish evaluating the mechanical properties of components made by the new magnetic composite material by 6/30/2022. Dog bone samples have been made and testing is in progress. Overall, the project is on track.

**Reviewer 4**

The reviewer said it is hard to quantify based on the provided information and the expected benefits of the proposed material. At least motor simulation results should be provided.

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

**Reviewer 1**

The reviewer thinks the project collaborates well with other national labs and universities, i.e., Purdue and Illinois Institute of Technology-Chicago.

**Reviewer 2**

The reviewer said collaboration between team members is well coordinated.

**Reviewer 3**

The reviewer remarked the team has made excellent use of the facilities at NREL and Ames National Laboratory for physical property measurements unable to be performed at SNL. Other than the homopolar motor concept from Purdue University, the contributions from the other partners was not presented.

**Reviewer 4**

The reviewer commented the roles of all the partners are not very clear; for example, there seems to be an overlap between Purdue, Illinois Institute of Technology, and ORNL.

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

**Reviewer 1**

The reviewer said the team has a clear goal to improve the saturation polarization from 1.19 T to 1.89 T as the volume loading increases.

**Reviewer 2**

The reviewer said the project needs more quantification of material properties and motor performance.

**Reviewer 3**

The reviewer remarked measurement of the mechanical properties will be critical towards understanding the ability of this material to perform in an electric machine. More detail on the prototype motor designs under consideration should be presented in future reviews.

**Reviewer 4**

The reviewer said future work includes mechanical testing and improving the soft composite material performance. The reviewer asked is it possible to show an example motor design using the properties of the soft magnetic material that would be useful to show next year.

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

**Reviewer 1**

The reviewer said an improved soft magnetic material with lower losses can help meet the DOE targets.

**Reviewer 2**

The reviewer remarked yes, the project is relevant to the Electrification subprogram. Meeting the performance goals on the DOE roadmap will require advances in magnetic material performance.

**Reviewer 3**

The reviewer remarked the project explores new magnetic material to improve the power density for traction machines for electrified vehicles.

**Reviewer 4**

The reviewer said the project supports the VTO subprogram objectives related to motor design using on-HRE materials. The reviewer asked is it possible to design a motor and inductor using this material in the future? What would it take to create a sample rotor and stator?

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

**Reviewer 1**

The reviewer said resources are sufficient based on the proposed scope.

**Reviewer 2**

The reviewer remarked resources are sufficient to meet the goals of the project.

**Reviewer 3**

The reviewer said it appears that resources are sufficient.

**Reviewer 4**

The reviewer commented the team has excellent resources to perform the planned research.

**Presentation Number: elt217**
**Presentation Title: Integrated/Traction Drive Thermal Management**
**Principal Investigator: Bidzina Kekelia, National Renewable Energy Laboratory**

***Presenter***

Bidzina Kekelia, NREL

***Reviewer Sample Size***

A total of three reviewers evaluated this project.

***Project Relevance and Resources***

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

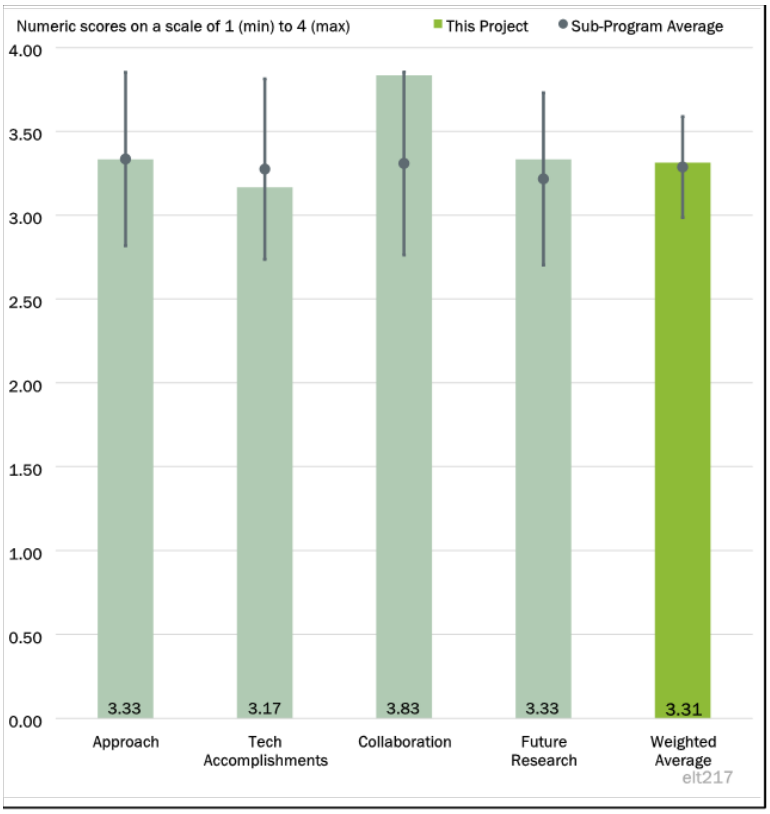


Figure 4-11 - Presentation Number: elt217 Presentation Title: Integrated/Traction Drive Thermal Management Principal Investigator: Bidzina Kekelia, National Renewable Energy Laboratory

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

**Reviewer 1**

The reviewer said using a common cooling structure for the motor and inverter is indeed a step towards integrated traction drive for vehicles. A single fluid which is electrically insulated and thermally conducting could be quite helpful for simplifying integrated traction drive, where the inverter and motor are integrated together.

This reviewer raises concerns related to cooling fluid leaks that could occur under drive system enduring unwanted vibrations faced by the integrated drive system deployed in vehicles. Also, there could be manufacturing challenges and that could come with supply chain related challenges and end users may never be able to overcome these challenges, resulting in no or limited commercialization of technology under development through this project.

**Reviewer 2**

Generally, the approach makes sense to this reviewer. The thermal management system (TMS) design for the stator windings and power electronics inside the hollow area is complete. However, when integrating the manifolds and cooling channels, there are still some underlying risks like coolant leakage, imperfect contact between T-shape heat exchanger and windings, high pressure drop, etc. These risks can be addressed with hardware iteration.

**Reviewer 3**

The reviewer said the team uses a T-shape heat exchanger buried between windings to dissipate heat, and a single integrated cooling loop for motor and power electronics. It is an innovative idea. The reviewer suggests the team compare the cooling performance of this design to the traditional end-winding dripping cooling. Although the T-shape heat exchanger is built of material with high thermal conductivity, the air gap between the winding and the heat exchanger still presents a high thermal resistance. Therefore, the reviewer is concerned this design might not have better performance than the traditional end-winding dripping cooling, where automatic transmission fluid directly contacts the winding. If the cooling is not more effective, it would be difficult to meet the power density target for the motor/drive system.

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

**Reviewer 1**

The reviewer said the team's FY's 2022's goal is to manufacture and test subcomponents of the integrated machine and drive cooling system by September 2022. The design is completed and manufacturing is on-going. Overall, the project is on track in terms of schedule.

**Reviewer 2**

The reviewer remarked the concept of the integrated drive system has been evolved including T-shaped heat-exchanger. The T-shaped heat-exchanger will be inserted in motor windings and will transport coolant back and forth from manifold disk. The manifold disk will have O-ring type sealing to prevent fluid leak to power-electronics in motor interior cavity. All these concepts are very well evolved along with completion of some computational fluid dynamics investigations. The reviewer noted the rest of tasks are tracking well including milestone due on 9/30/2022.

**Reviewer 3**

The reviewer remarked without experimental testing, many of these issues cannot be evaluated. The hardware build is a little lagging behind. This is the fourth year. However, no experimental results or samples are discussed. There might not be enough time left for one more iteration when any issues are found.

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

**Reviewer 1**

The reviewer remarked all project partners, drawn from ORNL, NREL and the University of Wisconsin-Madison, are collaborating well.

**Reviewer 2**

The reviewer said collaboration inside and outside the Electric Drive Technologies (EDT) consortium look good. Electrical machine design as well as integrated motor drive design are making progresses owing to the support from NREL.

**Reviewer 3**

The reviewer said the team's collaboration is well coordinated.

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

**Reviewer 1**

The reviewer said future work is clearly stated in the project report with research tasks identified for each project partners.

**Reviewer 2**

The reviewer is okay with the three specific tasks of building components. Maybe, add a plan for subsystem thermal performance testing before integrating them as the final TMS.

**Reviewer 3**

The reviewer said the project clearly defined a purpose for future work, but the team is encouraged to demonstrate more data (simulation or/and testing) in the coming quarters to show the performance of the new cooling system and as compared against the traditional traction machine and drive thermal management system.

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

**Reviewer 1**

The reviewer affirmed the project supports VTO's goal of more compact electric drive system.

**Reviewer 2**

The reviewer said this keystone project supports DOE-EDT consortium members by collaboration among DOE labs (ORNL and NREL) and University of Wisconsin-Madison. Project activities will eliminate cost, power-density barriers faced by state-of-the-art electric drives presently used in vehicle while achieving reliability (300,000 miles) and lifetime (15 years) targets.

**Reviewer 3**

The reviewer noted this advanced TMS design project is of paramount importance for high performance electrical machine system design. So, it is absolutely relevant to VTO goals and scopes.

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

**Reviewer 1**

The reviewer said the project has all necessary resources including engineering and technical expertise.

**Reviewer 2**

The reviewer noted that NREL has abundant experience with innovative TMS design. It has good connections with vendors that can provide support. The reviewer did not see any issues in terms of resources.

**Reviewer 3**

The reviewer said the team has excellent resources to conduct the research.

**Presentation Number: elt218**
**Presentation Title: Advanced Power Electronics Designs-Reliability and Prognostics**
**Principal Investigator: Doug DeVoto, National Renewable Energy Laboratory**

### *Presenter*

Doug DeVoto, NREL

### *Reviewer Sample Size*

A total of five reviewers evaluated this project.

### *Project Relevance and Resources*

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

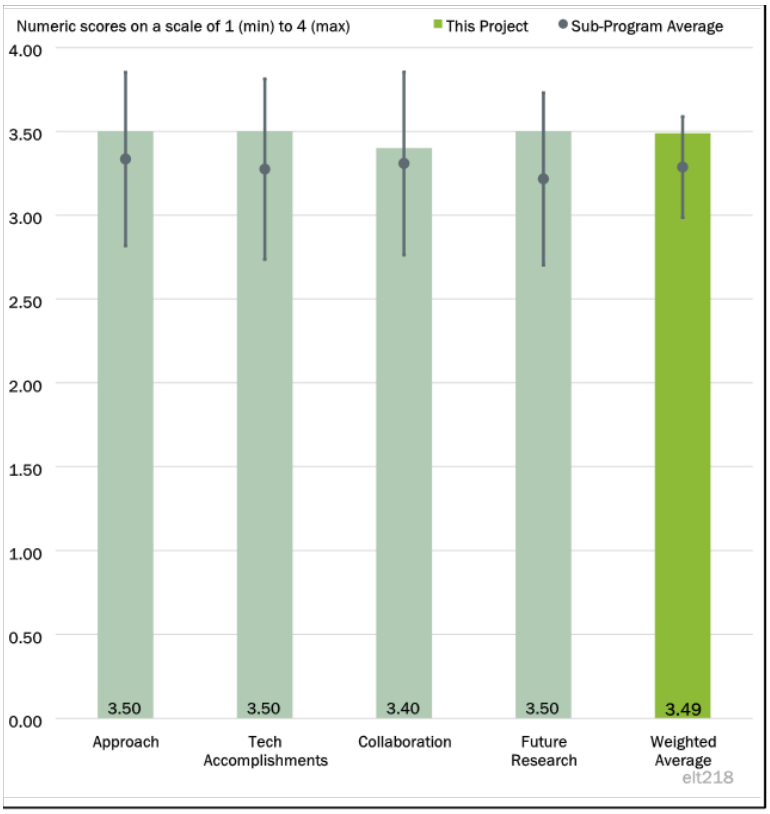


Figure 4-12 - Presentation Number: elt218 Presentation Title: Advanced Power Electronics Designs-Reliability and Prognostics Principal Investigator: Doug DeVoto, National Renewable Energy Laboratory

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

**Reviewer 1**

The reviewer remarked the project addresses materials-related aspects of WBG devices by studying a unique approach for more robust mechanical design. The project addresses fundamental questions that need to be answered to enable device development. Like some of the other related projects, involvement of a manufacturer that makes these devices would be very helpful.

**Reviewer 2**

The reviewer said the team has a clear, well-thought approach to the project.

**Reviewer 3**

The reviewer said the project team is using a well-known industrial process in packaging of WBG power devices using organic direct-bond copper (ODBC). This could positively impact commercialization of these devices. Additionally, using ODBC allows higher operating temperature while eliminating issues related to hot spots led by high heat fluxes, which could lead to a reliable system level power conversion solution. The reviewer noted this project aims to address thermal and reliability concerns by designing new packages of WBG devices followed by evaluation of WBG power devices under accelerated condition to assess reliability and durability needed in a real-word application of these devices.

**Reviewer 4**

The reviewer said this project has identified a very important bottleneck in power electronics miniatuirzation and correctly addressed that through discovery and application of new materials and processes.

**Reviewer 5**

The reviewer remarked program level requirements are never defined. Design and testing targets for the performance and reliability of the bonding and material solutions are not well understood. The reviewer said the PI mentioned that "new package designs must overcome thermal and reliability concerns", why is this necessary? The reviewer struggles to understand why this project is important. Why do we care?

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

**Reviewer 1**

The reviewer said the project team has made excellent progress and is on track to deliver milestone.

**Reviewer 2**

The reviewer said excellent progress in testing new materials for WBG and developing designs and methods for employing them in WBG devices.

**Reviewer 3**

The reviewer said excellent technical accomplishments were made on the feasibility of new design and materials use.

**Reviewer 4**

The reviewer remarked the team has accomplished a great deal on thermal characterization of the insulated substrates.

**Reviewer 5**

The reviewer commented the bonding and material development accomplishments that are performed by the project are well documented. Is the test plan defined on Slide 9 the de facto testing requirement to be used for all component solutions?

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

**Reviewer 1**

The reviewer said excellent partners for the team.

**Reviewer 2**

The reviewer noted that NREL is closely working with ORNL and industry partners to evaluate new packaging materials and manufacturing techniques for WBG-based traction inverters. In the project Indiana Integrated Circuits (IIC) is supporting/providing chip-to-chip edge interconnection for these devices using IIC's quilt packaging technology. The reviewer noted that DuPont's ODBC substrate is used to replace ceramic substrate. Therefore, collaboration among various entities in the project team is as expected for successful completion of this project.

**Reviewer 3**

The reviewer said contributions from partners are well integrated, though collaboration would be improved with a device manufacturer. Does IIC fit the bill? The reviewer is under the impression their main contribution is the direct-interconnect method.

**Reviewer 4**

The reviewer would like to see more documentation and discussion about partners efforts on the collaboration slide.

**Reviewer 5**

Team has outstanding collaboration network between material, design and process.

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

**Reviewer 1**

The reviewer remarked the project has outlined excellent future research and path forward.

**Reviewer 2**

The reviewer remarked valid and necessary points for follow up work.

**Reviewer 3**

The reviewer said next steps are appropriate.

**Reviewer 4**

The reviewer said future research tasks are stated out in the project report and will support project objectives.

**Reviewer 5**

The reviewer was unclear if the team plans to fabricate the double-side-cooled half-bridge modules in house or subcontract it out.

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

**Reviewer 1**

The reviewer noted that WBG power devices with improved packaging are needed to meet DOE ELT 2025 targets including 300,000 miles and/or 15 years life reliability while meeting 100 kW/L power-density and $2.7/kW cost targets. ODBC-based WBG power devices packaging technology fulfill DOE ELT 2025 objectives.

**Reviewer 2**

The reviewer said this project supports fundamental work needed to advance WBG power electronics and their performance benefits for EV performance (higher range due to improved efficiency, mass reduction).

**Reviewer 3**

The reviewer affirmed yes, the work is critical for DOE VTO to achieve its objectives.

**Reviewer 4**

The reviewer cannot determine if the project supports the overall VTO objectives because they are never listed in the presentation. I suspect that these advances are necessary for future power electronics componentry due to down sized package limits and higher power levels, but that understanding is never proven in the presentation.

**Reviewer 5**

The reviewer said as commented earlier, this project targets to resolve extremely critical issues for power electronics miniaturization.

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

**Reviewer 1**

The reviewer said resources appear adequate.

**Reviewer 2**

The reviewer said sufficient, unless the yield of module fabrication is too low.

**Reviewer 3**

The reviewer remarked the project team has all necessary resources and excellent know-how on background technology that is necessary for successful completion of this project for ODBC-based high reliability and thermal performance WBG power devices.

**Reviewer 4**

The reviewer said this project has sufficient resources.

**Reviewer 5**

The reviewer said resources are okay.

**Presentation Number: elt221**
**Presentation Title: Integrated Electric Drive System**
**Principal Investigator: Shajjad Chowdhury, Oak Ridge National Laboratory**

***Presenter***

Shajjad Chowdhury, ORNL

***Reviewer Sample Size***

A total of five reviewers evaluated this project.

***Project Relevance and Resources***

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

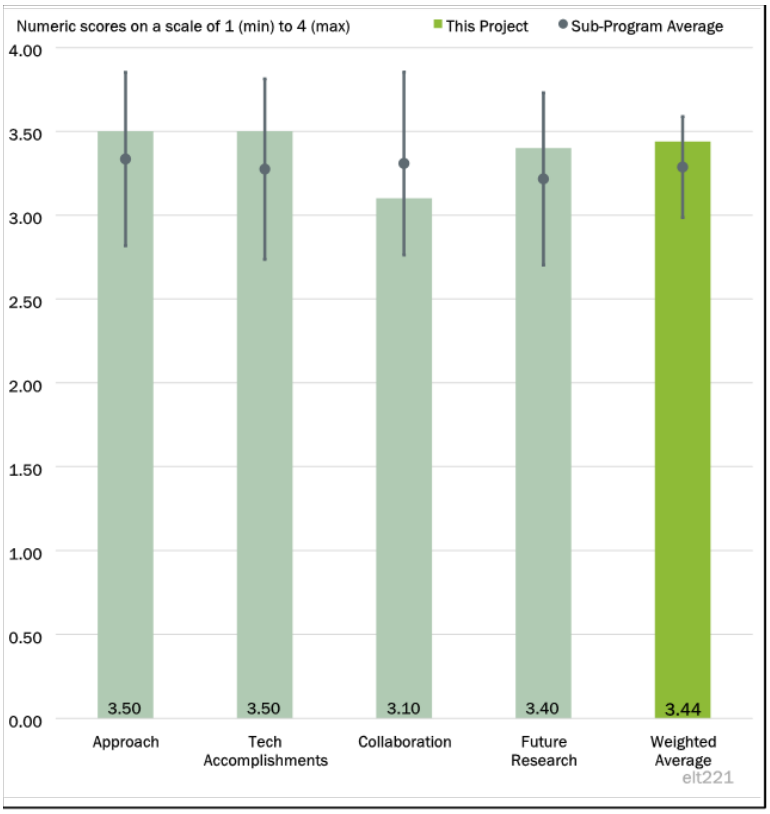


Figure 4-13 - Presentation Number: elt221 Presentation Title: Integrated Electric Drive System Principal Investigator: Shajjad Chowdhury, Oak Ridge National Laboratory

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

**Reviewer 1**

The reviewer said the approach is well-planned.

**Reviewer 2**

The reviewer noted that technical barriers namely space and thermal constraint have been correctly identified in this project and addressed as per initial design.

**Reviewer 3**

The reviewer said good approach, although more discussion next year about milestones would be interesting, and requirements are tied to program goals.

**Reviewer 4**

The reviewer said the integrated machine and drive with shared TMS is promising for high-power density design. Outer rotor, surface-mounted PM, and fractional slot concentrated windings are helpful for achieving high torque design. The only concern the reviewer had is that this type of machine (outer rotor, surface-mounted PM, and fractional slot concentrated windings) is barely used in traction applications due to high losses, limited maximum rotating speeds, and high magnet usage.

**Reviewer 5**

The reviewer said the substrate heat spreading study regarding insulated metal substrate with thermally annealed pyrolytic graphite (IMSwTPG) seems like a bit of a distraction because there seemed to be no clear plan or path to fabrication of this substrate based on comments from the speaker during the presentation. Thus, it might be better to focus more clearly on the remaining challenges and work for FY 2022.

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

**Reviewer 1**

The reviewer commented technical accomplishments are progressing and on track.

**Reviewer 2**

The reviewer said the project accomplishments are nice. The capacitor study in particular is well conceived and the results are informative and interesting and show the benefit of the packaging approach.

**Reviewer 3**

The reviewer remarked the team has accomplished several technical milestones specially around capacitor design and characterization.

**Reviewer 4**

The reviewer said good work, and I would appreciate a summary of accomplishments at the end of the presentation.

**Reviewer 5**

Regarding technical accomplishments, the reviewer had the following four comments: First, regarding TMS design, it is not immediately clear that motor stator losses are considered. Or, it is just for PEs. The impression is that the thermal management system is not sufficient for both EM and PE. Second, regarding circular package: the temperature of the capacitors in the inner circle cannot be seen. Highest temperature is expected to be seen there (Slide 9). Third, bearing price and maximum speed are not explained. Also, bearing inner surface (85C coolant) could be warmer than outer, which might result in mechanical tolerance/alignment, and extra losses issues. Fourth, after installation, how easy/hard can we replace and fix modules when there is a failure?

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

**Reviewer 1**

The reviewer said collaboration is on track.

**Reviewer 2**

The reviewer said collaborations look good. NREL takes care of TMS, SNL is providing WBG devices, and Ames National Laboratory is developing advanced magnetic materials. These are the three important areas for this project.

**Reviewer 3**

The reviewer said the project has a very good design of the collaboration scope. However, it would be good to see how is that being included in the test design in more detail, especially around experimentation on thermal characterization with NREL.

**Reviewer 4**

The reviewer was unclear how the Ames National Laboratory work fits into the project.

**Reviewer 5**

The reviewer said the broader aspects of ELTt221 in the context of the larger collaboration were touched upon but were not a major part of the presented work.

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

**Reviewer 1**

The reviewer said it is critical to overcome the thermal challenges with substrates.

**Reviewer 2**

The reviewer said good list of future activities.

**Reviewer 3**

The reviewer remarked the project team has righty identified future research.

**Reviewer 4**

The reviewer recommended doing some level of subsystem testing involving TMS design as soon as possible. Cooling performance is a huge unknown at this point.

**Reviewer 5**

The reviewer said the role of the substrate heat transfer study in informing future work was not clear and could be improved.

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

**Reviewer 1**

The reviewer said an important work toward improving the overall performance.

**Reviewer 2**

The reviewer said yes, the machine/drive integration theme is highly relevant for future electrified powertrain development.

**Reviewer 3**

The reviewer said well-defined requirements and goals, as well as on the summary slide.

**Reviewer 4**

The reviewer noted the project is addressing VTO targets on energy and power density.

**Reviewer 5**

The reviewer said this project supports the overall VTO subprogram objectives.

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

**Reviewer 1**

The reviewer said resources are on track.

**Reviewer 2**

The reviewer remarked resources are sufficient for the proposed FY 2022 work.

**Reviewer 3**

The reviewer said the future scope of this work is properly identified; however, targets are very aggressive and the project may need additional resources.

**Reviewer 4**

The reviewer said the team is pretty strong, though there may be a lack of an industry partner. And, that is why the machine design (FSCW-SPM) is not similar to the mainstream of EV powertrain products.

**Reviewer 5**

The reviewer said resources are difficult to judge because the total project budget is never listed.

**Presentation Number: elt236**
**Presentation Title: Direct-Current Conversion Equipment Connected to the Medium-Voltage Grid for Extreme Fast Charging Utilizing Modular and Interoperable Architecture**
**Principal Investigator: Watson Collins, EPRI**

***Presenter***

Watson Collins, EPRI

***Reviewer Sample Size***

A total of two reviewers evaluated this project.

***Project Relevance and Resources***

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

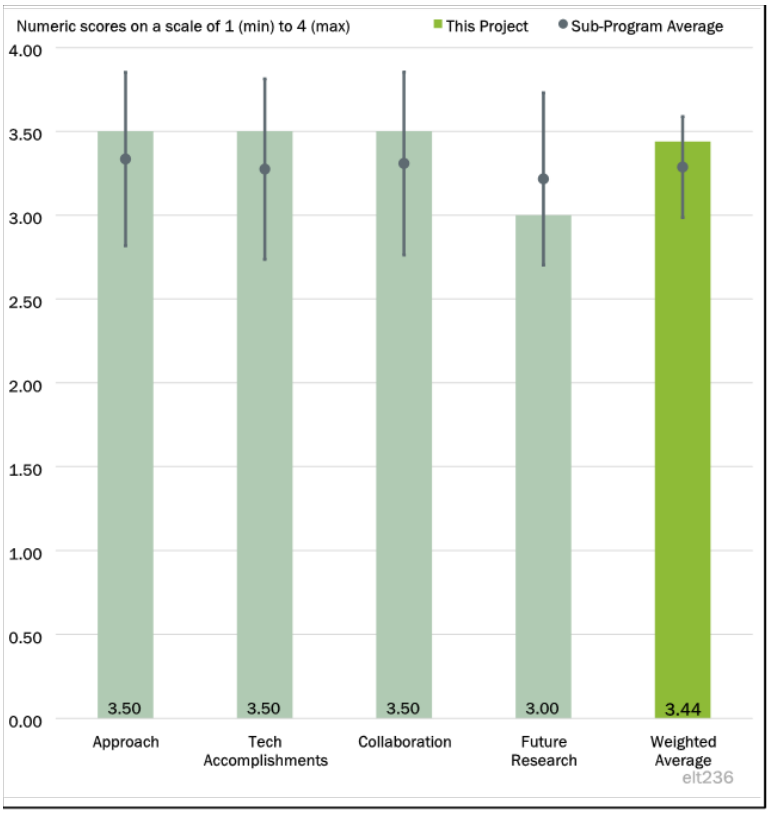


Figure 4-14 - Presentation Number: elt236 Presentation Title: Direct-Current Conversion Equipment Connected to the Medium-Voltage Grid for Extreme Fast Charging Utilizing Modular and Interoperable Architecture Principal Investigator: Watson Collins, EPRI

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

**Reviewer 1**

The reviewer said the project is well designed with the appropriate teaming strategy and technical barriers addressed. This project is relevant for future EV charging infrastructure needs.

**Reviewer 2**

The reviewer remarked the project is well defined and the timeline is reasonable. Contingencies are in place to address potential testing site and vehicle availability issues.

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

**Reviewer 1**

The reviewer commented the project appears to be on schedule.

**Reviewer 2**

The reviewer said overall, good progress. Need a little more explanation why the utility interconnection interface is delayed, because this is an important aspect.

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

**Reviewer 1**

The reviewer said this is a good team with OEMs, national labs, universities, charging companies, and utilities, and all seem to be contributing.

**Reviewer 2**

The reviewer remarked strong collaboration among project team members has been demonstrated with specific contributions from industry.

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

**Reviewer 1**

The reviewer said proposed future work supports application, industry, and fleet needs.

**Reviewer 2**

The reviewer remarked the identified opportunities are all important, but the project is missing a crucial component: economic analysis and cost benefit evaluation.

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

**Reviewer 1**

The reviewer said this project supports and aligns very well with the ELT subprogram objectives.

**Reviewer 2**

The reviewer said the project is relevant in supporting the VTO program and DOE goals.

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

**Reviewer 1**

The reviewer said the project appears to be sufficiently resourced and on track to complete the project.

**Reviewer 2**

The reviewer commented the resources dedicated to the project are in line with other efforts to support fast charging applications.

**Presentation Number: elt237**
**Presentation Title: Enabling Extreme Fast Charging with Energy Storage**
**Principal Investigator: Jonathan Kimball Missouri S&T**

***Presenter***

Jonathan Kimball Missouri S&T

***Reviewer Sample Size***

A total of three reviewers evaluated this project.

***Project Relevance and Resources***

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

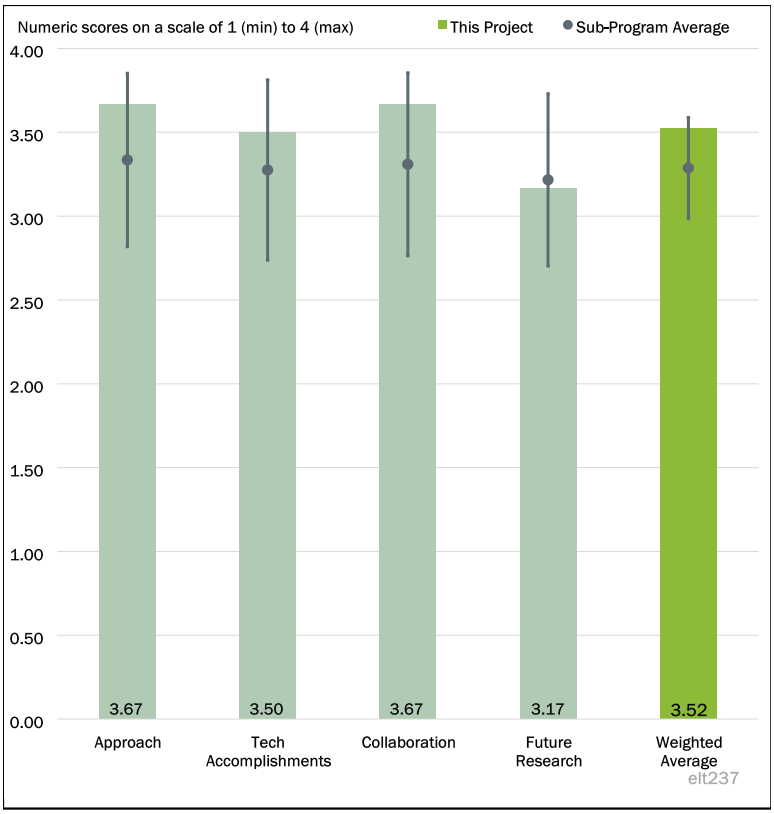


Figure 4-15 - Presentation Number: elt237 Presentation Title: Enabling Extreme Fast Charging with Energy Storage Principal Investigator: Jonathan Kimball Missouri S&T

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

**Reviewer 1**

The reviewer remarked the project has been phased by design and simulation leading to full scale system development and finally to system test and evaluation. This approach has proven effective in moving the project through budget period 1 and its objectives and well into budget period 2.

**Reviewer 2**

The reviewer said the project aims at developing the technology for EV charging station allowing rapid charging and minimum impact on grid and on battery. The project has four pillars covering both the grid side and the vehicle side: DC-DC power converter, charging algorithm, grid analysis, and battery pack on vehicle. The reviewer said this comprehensive and wholistic approach is the right approach to answer the need of economical fast charging.

**Reviewer 3**

The reviewer said the objective of mitigating battery degradation is being addressed with a charging algorithm which relies on specific technical data about the battery chemistry. This achieves the objective for this particular project because a battery is being developed for it. However, because battery chemistry is controlled by the vehicle OEM and a charger would presumably service a variety of vehicles, a key objective is not being met for the real world. Additionally, the reviewer would have expected to see some discussion on battery energy storage system (BESS) capacity sizing based on anticipated load, demand charges, availability of solar, and variable electricity rates.

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

**Reviewer 1**

The reviewer remarked the team made good progress. There are 4 tasks: power converter; cell/module/pack modeling and charge algorithm; grid analysis; and vehicle pack design. All tasks appeared to be on track. A full-scale power converter, module, and pack level charging algorithm, detailed and practical grid analysis, and vehicle pack design and construction are all complete. The remaining task is system integration and field testing. The project started in 2018. The reviewer said that even with the impact of COVID-19, the team managed to complete about 60% of the task while still having 25% of the project period remaining.

**Reviewer 2**

The reviewer said the project has a broad set of diverse objectives ranging from power electronics design to pack design and grid integration. Much of the schedule period was spent in budget period 1 doing design and simulation. The full-scale development and testing in budget period 2 will be the real test of how effectively barriers have been addressed.

**Reviewer 3**

The reviewer remarked the project is approaching its final year with significant work to be done. A stated objective for the period, 'Design and construct full-scale station' is not shown as being complete though the budget period is still ongoing and there is time to finish it.

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

**Reviewer 1**

The reviewer commented a diverse set of tasks have been advanced in a coordinated manner across the team to bring the extreme fast-charge (XFC) concept to the point of full-scale evaluation.

**Reviewer 2**

The reviewer said the Missouri S&T team works with Ameren (investor-owned utility), Bitrode (battery test equipment manufacturer), and LG Energy solution.

**Reviewer 3**

The reviewer said there appears to be good collaboration between all parties as the PI does not indicate that they are behind. The project completion percentage needs to increase significantly between now and the end of the budget period.

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

**Reviewer 1**

The reviewer said the proposed work appears to be reasonable.

**Reviewer 2**

The reviewer remarked system integration and field testing appear to be relatively short in duration. It is not clear that this will decisively demonstrate the new charging algorithm, nor the effectiveness of the energy storage across multiple use cases of varying numbers of vehicles charged and the spacing in time of charge events. The reviewer said a cost/benefit analysis would be most useful to potential commercial adoption of the

developed system. Should the new charge algorithm prove to be successful, it should receive investigation on its own.

**Reviewer 3**

The reviewer remarked there is not enough detail on the poster (perhaps more a limitation of the format). More information on time allowed for testing and type of testing would help. For example, it would be helpful to understand the various conditions/scenarios that will be tested to see how effectively the grid interface algorithm responds to variations from forecast demand.

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

**Reviewer 1**

The reviewer said EV charging is critical for a sustainable EV growth. The efforts on a new charging algorithm, new design of vehicle pack, low voltage low power and full power prototype, and grid interface for power and energy optimization are all important for improving charging efficiency and lower the cost. The project objectives and activities support overall VTO subprogram objectives.

**Reviewer 2**

The reviewer said blazing a new trail for infrastructure in the form of an XFC system is relevant in that it reveals unforeseen barriers that must be addressed to make implementation successful. Should the new charge algorithm prove to be successful, it will be a significant improvement in XFC technology and should receive investigation on its own.

**Reviewer 3**

The reviewer commented the project addresses advances in charging but it could be doing it in a very narrow fashion in two areas: The objectives of minimizing battery degradation can only be met for a specific battery which may not exist in the real world, and there is no discussion on how BESS and solar capacity should adjust based on variability in the cost function.

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

**Reviewer 1**

The reviewer said the project has sufficient resource to accomplish the planned technical milestones.

**Reviewer 2**

The reviewer remarked the project has engaged key technical resources in the areas it is developing technology. Their commitment appears to be sufficient as the project in on schedule for full testing in 2023.

**Reviewer 3**

The reviewer commented the project appears to have appropriate partners and the PI did not express a concern regarding resources.

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

### *Presenter*

Srdjan Lukic, North Carolina State University

### *Reviewer Sample Size*

A total of four reviewers evaluated this project.

### *Project Relevance and Resources*

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

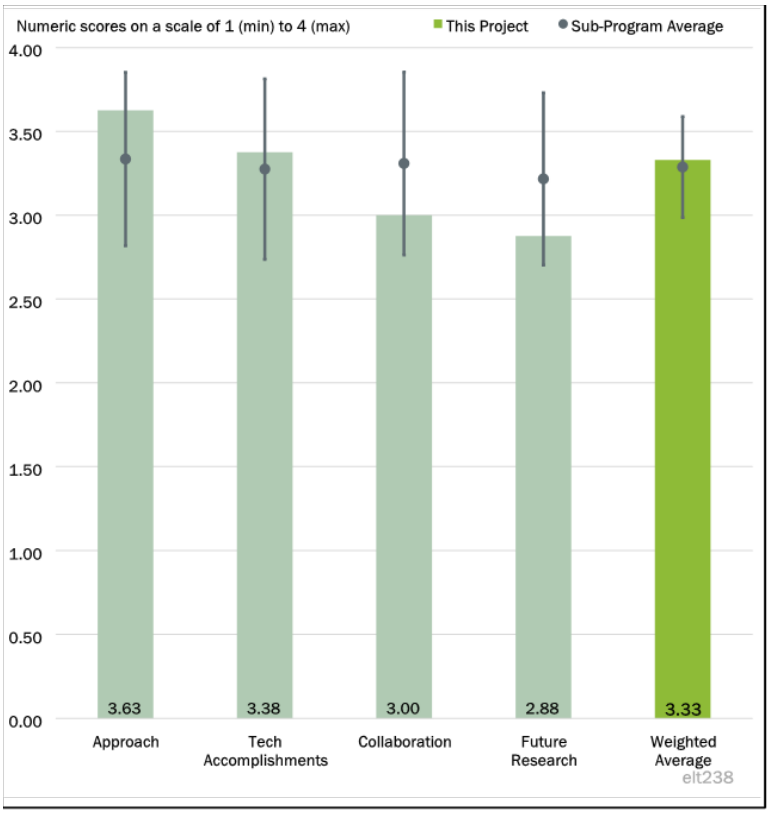


Figure 4-16 - Presentation Number: elt238 Presentation Title: Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State Direct-Current Protection Principal Investigator: Srdjan Lukic, North Carolina State University

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

**Reviewer 1**

This reviewer pointed out that one technical barrier was a lack of an available energy management platform with the required functionality. The team developed the needed system to demonstrate the system's operations without losing focus on the primary goals of the project. Another barrier, according to the reviewer, was the lack of a domestic provider of a DC/DC EVSE meeting the project's needs, so the team designed, developed, and built a prototype that could be used for the system deployment and testing.

**Reviewer 2**

This reviewer found that the overall approach to the project is outstanding. It is well designed, though it seems the project is delayed.

**Reviewer 3**

This reviewer said that the project approach is a very good way to solve an important charging barrier. The project is focused on developing and deploying a 1MW medium voltage XFC station with a shared bi-directional solid-state transformer (SST) connecting to the medium voltage distribution system. Additionally, a

DC distribution network with solid-state DC protection, an energy management platform, and local isolation are being integrated as part of the charging system solution.

**Reviewer 4**

This reviewer noted that, given the supply chain constraints, a one-year no cost extension seems reasonable.

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

**Reviewer 1**

This reviewer said that significant technical accomplishments include: DC solid state circuit breakers (SSCB) have been constructed and tested; SST lab prototype constructed and integrated with SSCB and tested; field SST under construction and first module successfully tested and characterized; final DC/DC stage testing underway.

**Reviewer 2**

This reviewer found that the team has demonstrated most but not all of the required functionality. Specifically, testing of main source and BESS source faults needs to be completed successfully. On the positive side, the SSCB has achieved coordination in less than 10 microseconds, a 1,000-fold improvement compared to currently available technology and sufficient to realize the overall vision of a charging station with an SST connection to the grid and a local DC distribution network. The project has also achieved impressive functional improvements, achieving 50% or better reductions in volume, mass, and pad size for charger installations, while increasing efficiency from 92% to 96%, i.e., reducing losses by 50% from 8% to 4%.

**Reviewer 3**

This reviewer said that good progress is being made.

**Reviewer 4**

This reviewer commented that, given a 1 MW charging approach, the reviewer did not see a reference to CharIN and asked how does this project address current standards development for 1 MW charging.

Additionally, the reviewer asked how the new standards that are being proposed with NEVI funding, including Plug and Charge, are being taken into account? Finally, the reviewer did not see cyber security addressed anywhere in the presentation.

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

**Reviewer 1**

This reviewer found strong partnership with contributions from ABB (solid state breaker development and testing), New York Power Authority system deployment and demonstration), and North Carolina State University FREEDM Systems Center (SST and DC Node development and XFC system integration).

**Reviewer 2**

This reviewer said that excellent collaborations are happening.

**Reviewer 3**

This reviewer believed that the project team appears to be working well together. However, the team does not include an electric vehicle service provider (EVSP), even though last year's reviewers commented that having an EVSP on the team is important. According to the reviewer, an EVSP is, in fact, critical, because EVSPs are the entities leading the design and construction of charging depots and, thus, the entities that will decide whether or not to implement this technology commercially. The lack of an EVSP's participation was the one major flaw the reviewer found with this program.

**Reviewer 4**

This reviewer believed that the project could benefit from additional stakeholders, including an EVSE provider, additional utility partners, and an automaker.

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

**Reviewer 1**

This reviewer noted that future work of system assembly, integration, and field testing to complete the remaining 20% of the project was appropriate.

**Reviewer 2**

This reviewer said that the proposed future work, as presented, was exactly right, namely the assembly, integration, commissioning and field testing. While the focus of this project is the technology and field demonstration, a key goal of the VTO is to commercialize technologies, not simply fund "science projects." Accordingly, the future work should include additional analysis of the commercial deployability of the technology. Various barriers, including supply chain barriers, have already been identified, so the team has valuable lessons learned that can be made available to potential users of this technology. This aspect of the future work should also consider manufacturability, which should be readily possible, given that ABB is on the team.

**Reviewer 3**

The reviewer did not see timelines for the future work. In that sense, the reviewer believed that it could be better defined.

**Reviewer 4**

This reviewer said that the cost increase and supply chain disruptions are significant. The proposed research is the heart of actually putting the project together for demonstration.

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

**Reviewer 1**

This reviewer said that the project is relevant to VTO Grid Integration subprogram as it supports EV extreme fast charging station development with direct connection to the medium voltage distribution network.

**Reviewer 2**

This reviewer said that the project specifically supports VTO's high-power charging (HPC) objective for 2023, which states, "HPC: Develop strategies and technologies for...multi-port 1+ MW charging stations that enable vehicle charging through direct connection to medium voltage (≥ 12.47 kV) distribution."

**Reviewer 3**

This reviewer found that the project has strong relevance and supports the VTO subprogram objectives.

**Reviewer 4**

This reviewer said that the project supports electrification.

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

**Reviewer 1**

This reviewer said that the funding seems appropriate—$2.7 million DOE share and $3.3 million contractor share make for a significant project that is addressing an important barriers to enable large scale electrification of the transportation sector

**Reviewer 2**

This reviewer said that the project team has stayed on plan with respect to budget, though the schedule has been delayed due to supply chain issues. The team will request a one-year extension to make up for the delay, but no additional resources will be requested (or needed).

**Reviewer 3**

This reviewer believes that the resources appear sufficient, but the PI should address the reasons for the delays, and the timelines for the future/remaining tasks.

**Reviewer 4**

This reviewer said that sufficient resources for the project exist.

**Presentation Number: elt239**
**Presentation Title: High-Power Inductive Charging System Development and Integration for Mobility**
**Principal Investigator: Omer Onar, Oak Ridge National Laboratory**

***Presenter***

Omer Onar, ORNL

***Reviewer Sample Size***

A total of three reviewers evaluated this project.

***Project Relevance and Resources***

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

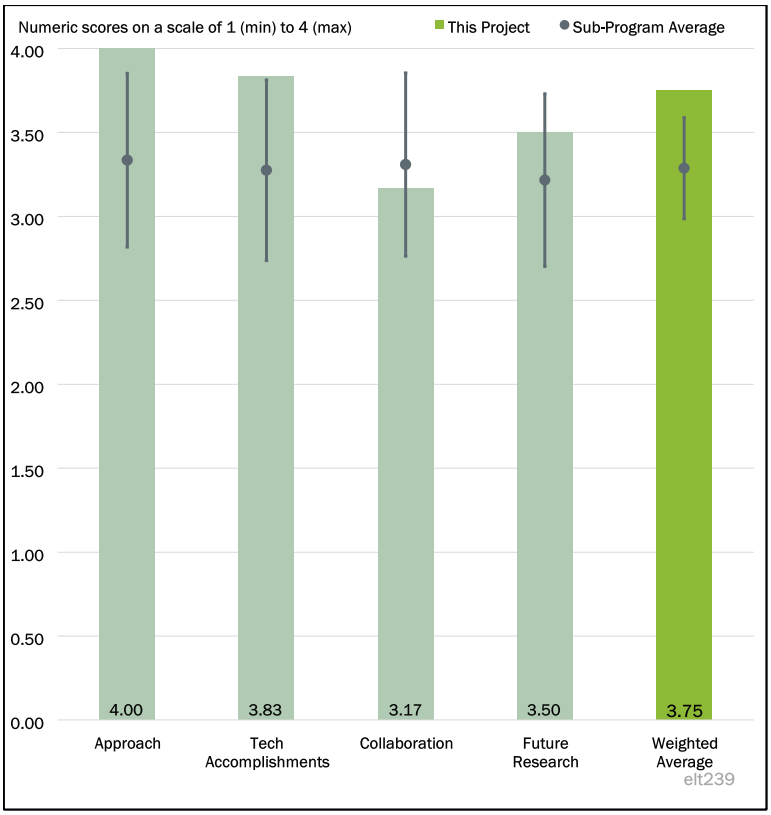


Figure 4-17 - Presentation Number: elt239 Presentation Title: High-Power Inductive Charging System Development and Integration for Mobility Principal Investigator: Omer Onar, Oak Ridge National Laboratory

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

**Reviewer 1**

This reviewer said that the approach is novel with a modular approach to coil utilization.

**Reviewer 2**

This reviewer said that the approach seems to be well thought-out, allowing for methodical progress toward project goals. An iterative design appears to have been critical, allowing for development of components and systems in stages, testing, and then redesigning, resulting in a highly effective overall system.

**Reviewer 3**

This reviewer found that the project team's approach was to model, test, and validate. The PI explained the design choices on the polyphase coil technology, which generates rotating magnetic fields and allows for a more compact system.

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

**Reviewer 1**

This reviewer noted that hardware design has been completed and is going through bench-scale testing. Once done with testing, the demonstration systems (100 and 270 kW) will be hooked up to the test vehicles. Thus, the project seems to be moving along as planned and has completed a large number of activities. The team also appears to have developed a coupler system that has increased surface power density by an order of magnitude over existing couplers. The project's couplers are relatively small and light for transferring high charging rates. The project has also demonstrated 97.4%–98.8% coil-to-coil efficiency, very close to expected levels. Bench-scale testing at the 50kW level demonstrated over 95% overall efficiency. Initial results pointed to a small power loss from the design due to duplication, which pointed to a pathway to redesign to recapture the efficiency being lost. The team also found they can power phases individually, which can simulate a wide range of architectures to match a variety of potential vehicle charging receivers.

**Reviewer 2**

This reviewer pointed out that the project has several accomplishments. The reviewer appreciated the rotating field video showing the technology developed as part of this project. The design is able to double the effect of output voltage and the team can control phases independently. The polyphase coil is inter-operable with other coil designs, which is important when considering the roadway component. The reviewer also appreciated the size references and comparisons. The operating efficiency achieved is much greater than the required 90%. The project team has taken on an additional challenge of removing the liquid cooling system from the vehicle side to decrease the cost and complexity of EVs.

**Reviewer 3**

This reviewer found benchmarking, coil design, and technical performance evaluation to be robust.

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

**Reviewer 1**

This reviewer pointed out that ORNL is partnered with Hyundai and Volkswagen. While the team does not have an EVSE manufacturer on the team, it does have one that has licensed the technology, though deployment/installation is a few years off. ChargePoint was originally part of the proposal but pulled out. ORNL also indicated that it would be talking with the Electrify America (EA) side of VW to bring in its perspective and knowledge base. EA is interested in offering this system as an option for high-end charging units when the technology is ready.

**Reviewer 2**

This reviewer believed that the discussions and progress showed that coordination across the team members was good. Cybersecurity is an OEM requirement so the team is addressing it as part of the Electric Vehicles at Scale (EVs@Scale) Consortium. The OEMs also prefer a non-liquid cooling system on the car and the project team is looking at that as well. The team has been getting into discussions with EVSE through VW and HEVO.

**Reviewer 3**

This reviewer said that collaborator contribution was not highlighted to any great extent.

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

**Reviewer 1**

This reviewer said that the project team has clearly identified goals for future research, particularly as related to increasing surface power density even more to accelerate efficiency and thus charging speed. The team is also talking with Stellantis about other future improvements.

**Reviewer 2**

This reviewer said that the future work is with the OEMs to integrate and demonstrate the system at 100-kW and at 270kW. The 270kW is the limitation of the EV not the charging system. Additional phase systems were discussed and could be possible but more research would be needed.

**Reviewer 3**

This reviewer believed that the proposed future work is consistent with the project expectations and outcome. The reviewer would have preferred to see more details on future vehicle integration plans.

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

**Reviewer 1**

This reviewer said that the work broadly supports vehicle electrification and energy efficiency efforts.

**Reviewer 2**

This reviewer said that the project is extremely relevant—it is focused on increasing charging rates for EVs to move toward much quicker charging events closer in time to refueling with baseline petroleum fuels. The reviewer believed that that will be extremely important to support greater EV penetrations.

**Reviewer 3**

The reviewer said that this project supports high-power charging which is needed for a full EV transition in particular with fleet vehicles and those vehicles which are not able to charge in the home or depot location.

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

**Reviewer 1**

This reviewer said that the resources appear sufficient based on the outcomes of the project.

**Reviewer 2**

This reviewer believed that funds appear sufficient for this phase of development and that the team has identified future research needs for additional users.

**Reviewer 3**

This reviewer found that there were sufficient resources for the scope of this project.

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

***Presenter***

Mike Masquelier, WAVE

***Reviewer Sample Size***

A total of four reviewers evaluated this project.

***Project Relevance and Resources***

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

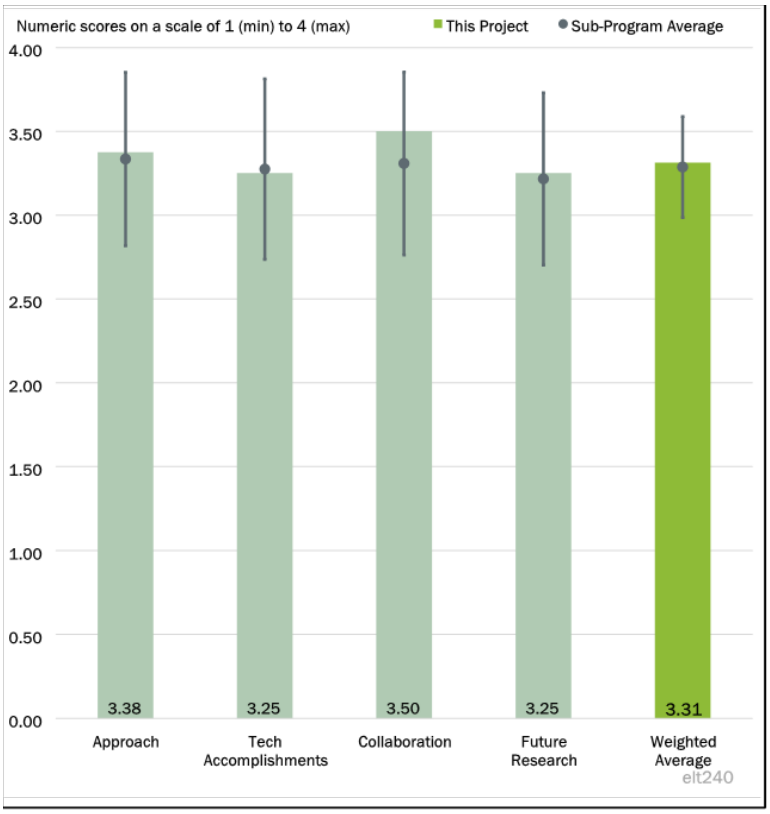


Figure 4-18 - Presentation Number: elt240 Presentation Title: Wireless Extreme Fast Charging for Electric Trucks (WXFC-Trucks) Principal Investigator: Mike Masquelier, WAVE

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

**Reviewer 1**

This reviewer noted that the project started in 2018 at the Port of Los Angeles. The budget is $10 million The objective is 20 minute full charge at 500 kW using 4160 volts input for higher system efficiency. The reviewer believes that the technical approach is sound.

Only 1,000 zero emission trucks sold last year out of 275k total HD sales. California needs usable/salable/user-friendly systems with a short wait for charging on return to the port to increase adoption, which this project is intended to help create. The cost is about the same for 250 and 500 kW systems. The reviewer believes that the project seems to be on schedule now after supply delays. It still needs UL compliance.

A full total cost of ownership must be developed but is that in the scope?

**Reviewer 2**

This reviewer said that the development and demonstration of the hardware looks good, suggesting that the team include use data for improvements in the simulation and virtual development of future system changes.

**Reviewer 3**

This reviewer noted that the team was able to demonstrate key objectives such as 500kW wireless charging early by using proven components. This is a time-tested approach and reduces development and production risk.

**Reviewer 4**

This reviewer was concerned that there are indicators that the project timeline has issues since the team is not demonstrating an integrated end-to-end system at the port as originally planned. It has geographically split up the project into non-integrated pieces where the MV conversion is tested in a lab and the charging at the port uses low voltage power to supply the wireless charger.

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

**Reviewer 1**

This reviewer believed that, other than supply chain issues, there were no impediments to progress reported. Therefore, according to the reviewer, it must be assumed that the project is running as designed and in the task order originally proposed.

**Reviewer 2**

This reviewer pointed out that, as mentioned in the oral presentation, with the exception of the MV system demo everything looks to be on time as described in the timeline. The demo of the MV charging system at a separate location should be good enough to prove out any potential efficiency improvements.

**Reviewer 3**

This reviewer said that good progress has been demonstrated by having both vehicles built and validated at Cummins, with production charging pads installed and the whole system tested. The team appears to be confident in its ability to demonstrate 500kW wireless charging, though work remains to be done on battery thermal management and validation of the charging process at the actual test site.

**Reviewer 4**

This reviewer expressed concerns that the technical progress of the MV conversion appears to have some weaknesses. According to the reviewer, it appears that, by performing the MV conversion in the lab that the development of the control process that coordinates MV conversion with the wireless charger via vehicles' CAN bus (as shown on the block diagram) will not be developed and demonstrated. Also the PI indicated that the MV conversion lab test will focus on measuring conversion efficiencies, but then indicated that he was unaware of any standards that should determine the requirements and hardware necessary for the MV conversion experiments.

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

**Reviewer 1**

This reviewer did not see any additional needs for the project.

**Reviewer 2**

This reviewer found that the partners are progressing together to complete the system and the demonstration.

**Reviewer 3**

This reviewer said that there appears to be good coordination between several of the partners that will result in a demonstration at the port.

**Reviewer 4**

This reviewer believed that progress on the hardware side of the project seems to indicate excellent collaboration. Production level 500kW designs are installed on the test trucks and charging in a test setting has been demonstrated. However, the reviewer was concerned that slow progress on the site may risk shortening the available validation period in the final budget period if anything else goes wrong.

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

**Reviewer 1**

This reviewer said that the future work clearly identifies several issues that the original project has not addressed.

**Reviewer 2**

This reviewer believes that the team should finish the development and do the demonstration rather than waiting to see whether this system operates well and is cost effective.

**Reviewer 3**

Most of the proposed future research lists items that are past the pre-competitive nature of DOE research. Developing better batteries, optimizing, improving system efficiencies, and lowering costs are a bit generic for proposed project research. Developing thermal materials, which the reviewer agrees is an important need for XFC in projects like this would likely be a different project.

**Reviewer 4**

This reviewer believes that it is not clear how directly the proposed future work is tied into meeting the goals for this project. For example, a BESS is mentioned to offset time of use (TOU) and demand charges but that is not one of the remaining barriers or objectives for this project. However, battery thermal management is a relevant area and may be needed for this project to meet the key deliverables.

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

**Reviewer 1**

This reviewer stated that drayage trucks at zero emissions has been a long standing challenge and this may be the first fully workable system to meet the need, making it very relevant.

**Reviewer 2**

This reviewer said that the proposed use of this technology in heavy duty and fleet customers is a pathway to quicker deployment of electric vehicle technology. The high speed recharging will improve end user utility for quicker adoption and displacement of GHGs.

**Reviewer 3**

This reviewer said that the project directly supports VTO subprogram objectives to reduce charging times for HD EVs and increase the efficiencies of EV charging.

**Reviewer 4**

This reviewer said that the demonstration will address a key barrier of uptime and availability in drayage (and other short distance/high uptime applications such as yard tractors, transit buses) and is therefore very relevant to the VTO objectives.

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

**Reviewer 1**

This reviewer said that, now that delays seem to be under control, the forward effort looks to be sufficient.

**Reviewer 2**

This reviewer said that the presentation shows the project being on track with the resources assigned. The project is nearing its completion and DOE funding is not the majority. Considering the are seven partners in the research, the resources appear sufficient to complete it.

**Reviewer 3**

This reviewer said that the project team appears to have the necessary resources.

**Reviewer 4**

This reviewer said that it appears that the resources provided to the project (e.g., funding and time) have been insufficient to perform an integrated end-to-end demonstration as planned and the team has adapted its approach to match the resource constraints.

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

***Presenter***

Charles Zhu, Delta Electronics

***Reviewer Sample Size***

A total of three reviewers evaluated this project.

***Project Relevance and Resources***

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

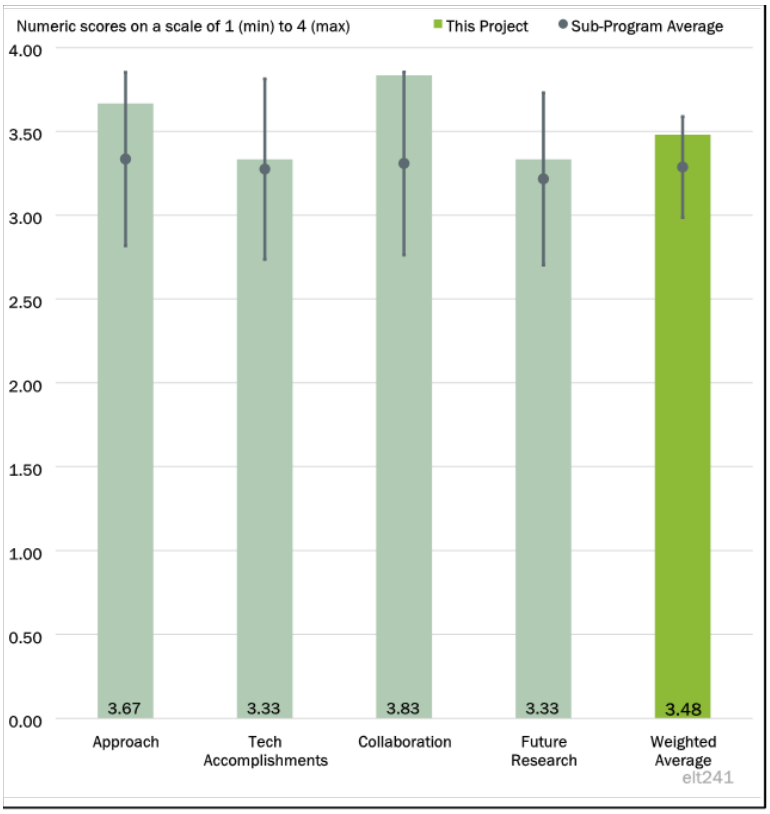


Figure 4-19 - Presentation Number: elt241 Presentation Title: High-Efficiency, Medium-Voltage Input, Solid-State, Transformer-Based 400-kilowatt (kW)/1000-V/400-A Extreme Fast Charger for Electric Vehicles Principal Investigator: Charles Zhu, Delta Electronics

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

**Reviewer 1**

This reviewer said that the results of the project speak for themselves. The project objectives have been completed, with only further demonstration with various vehicles remaining to be completed.

**Reviewer 2**

This reviewer felt that the approach (based on the concept and progress thus far) appears effective.

**Reviewer 3**

This reviewer believed that the overall approach to the project makes sense for achievement of intended goals. The team also designed the system to be highly compatible with renewable energy (solar) and storage, which can also help with demand/grid management.

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

**Reviewer 1**

This reviewer said that the work objectives have been achieved with only a small schedule extension resulting from COVID-19.

**Reviewer 2**

This reviewer said that the project seems slightly behind schedule but not in a major way.

**Reviewer 3**

This reviewer said that the project has progressed to the point of retrofitting the vehicle. There were some delays due to supply chain and Covid, but the project now seems to be moving ahead. Over the past year, the project did complete testing of the 400 kW/13.2kV unit with five different OEM baseline vehicles (non-retrofitted). Through testing, the team is now anticipating both increased efficiency (by 3%) and smaller footprint (by 50%) than comparable systems. The size improvement will also help future siting of the charging system (such as at conventional fueling stations). Testing has shown 97.5% peak efficiency, vs. a target of 96.5% peak. The team did testing at NextEnergy's site and also developed a second test/demonstration site (American Center for Mobility). Because of the delays, they have requested an extension. The project was scheduled to be completed May 2022, but will now be extended until November 2022.

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

**Reviewer 1**

This reviewer found that the collaborative aspects of the project were notable and well described/highlighted.

**Reviewer 2**

This reviewer noted that the team was large and has been effectively coordinated to build and evaluate both the XFC and multiple vehicles to demonstrate it with.

**Reviewer 3**

They assembled team was solid, including a vehicle manufacturer, an electronics firm, city/state agencies, a university, and two utilities. It has been working very closely together, focusing the efforts. In particular, GM has worked very closely with the project lead on the vehicle retrofit and NextEnergy provided a test site for the charger with several EVs (including a pre-production Cadillac Lyric provided by GM, plus several available vehicles) in order to show how the charger would be connected to the grid.

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

**Reviewer 1**

This reviewer said that the project team clearly identified the work remaining under the project. The principal investigator indicated an interest in looking at a multi-megawatt system for the next project .

**Reviewer 2**

This reviewer said that the project is 98% complete. The future work is a repeat of the validation work conducted at NextEnergy.

**Reviewer 3**

This reviewer regretted that greater details on how the minor schedule delay will be addressed through the project extension were not provided.

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

**Reviewer 1**

This reviewer said that the project is highly relevant to widespread adoption of EVs.

**Reviewer 2**

This reviewer said that the project is focused on extreme fast charging, which will be required to allow for quicker (near gasoline-speed) recharging to support greater electric vehicle penetrations into the market.

**Reviewer 3**

This reviewer said that the project provides a hardware baseline for establishing XFC as a viable strategy for EV infrastructure.

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

**Reviewer 1**

This reviewer said that the resources appear sufficient assuming the project extension adequately covers remaining work.

**Reviewer 2**

This reviewer said that funds appear to be sufficient to complete this phase.

**Reviewer 3**

This reviewer said that the project is nearly complete and has performed on schedule. This indicates sufficient resources were available.

**Presentation Number: elt252**
**Presentation Title: Wound-Field Synchronous Machine-System Integration toward Increased Power Density and Commercialization**
**Principal Investigator: Lakshmi Iyer, Magna Service of America Inc.**

### *Presenter*

Lakshmi Iyer, Magna Service of America Inc.

### *Reviewer Sample Size*

A total of four reviewers evaluated this project.

### *Project Relevance and Resources*

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

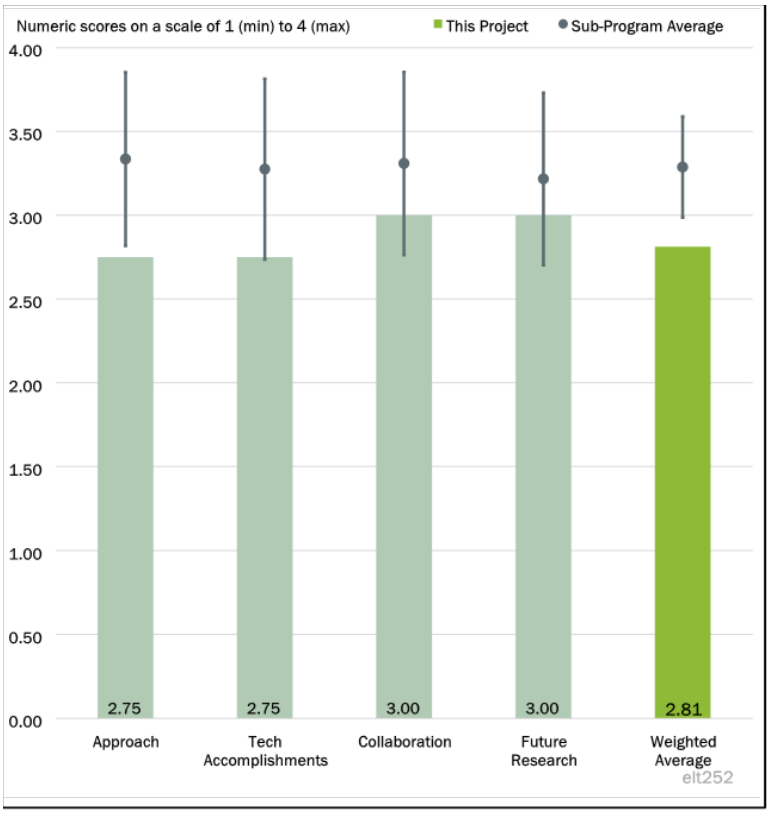


Figure 4-20 - Presentation Number: elt252 Presentation Title: Wound-Field Synchronous Machine-System Integration toward Increased Power Density and Commercialization Principal Investigator: Lakshmi Iyer, Magna Service of America Inc.

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

**Reviewer 1**

This reviewer said that, as non-permanent-magnet machines, wound-field synchronous machines are of interest/importance to industry but, it is not immediately clear how an eight fold increase in power density and nearly 96% efficiency can be achieved with the proposed design. The designs of the stator, rotor and TMS design look like those of a standard wound-field synchronous machine, especially after switching to inductive power transfer.

**Reviewer 2**

This reviewer said that the approach is very basic and didn't show a robust process to address the key project objectives

**Reviewer 3**

This reviewer commented that it is not clear what the key novelties in the project are, aside from optimization and evaluating different fairly standard cooling schemes. The reviewer further noted that the baseline design is not clear and the reference for the eight fold improvement in power density is not clear

**Reviewer 4**

This reviewer felt that, although the motor design was done systematically the motor's cost assessment does not appear to have been done. Testing to understand reliability/durability has not been included in the project. Both cost and reliability and durability of a technology must be an integral part of the project for a complete technology assessment, according to the reviewer.

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

**Reviewer 1**

major challenges with the cooling system and with meeting the power levels per the plan

**Reviewer 2**

(1) Clear quantitative comparison to a well-defined baseline is needed.

(2)Quantification of the impact of the identified limitation of CPT is needed.

**Reviewer 3**

The level of work given the funding level is solid. Yet the project does not encompass a full enough evaluation to be considered for automotive.

**Reviewer 4**

Regarding technical accomplishments, the reviewer had the following comments/questions. The multiphysics include electromagnetic design, cooling system (or TMS), mechanical analysis. How many of them are included in the global optimization? The reviewer was not clear how 8X power density and nearly 96% efficiency can be achieved with a standard-looked technology. After switching to inductive power transfer, the reviewer just worries that this project lose one of its major novelties. Finally, some benchmarking will be helpful to understand how it compares to existing products, e.g., GM, BWM or Renault WFSMs. These products are likely optimized as well.

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

**Reviewer 1**

This reviewer said that the project is led by industry (Magna) with support from University of Wisconsin-Madison and IIT. This collaboration will make sure that the design is feasible for production. The task assignment also looks good.

**Reviewer 2**

This reviewer said that there was a good level of collaboration and division of scope among the various partners.

**Reviewer 3**

This reviewer said that there is reasonable collaboration on the design and planning for manufacturing. But there is a tremendous gap in this project when considering the purpose of the program. Those missing elements would come from greater collaboration with industry.

**Reviewer 4**

This reviewer expressed a need to see specific actions and results by the partners.

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

**Reviewer 1**

This reviewer said that experimental testing will help verify the analytical predictions.

**Reviewer 2**

The suggested path forward would be of great interest to this reviewer, noting that taking advantage of GaN device performance attributes could lead to the development of a competitive advantage for industry.

**Reviewer 3**

This reviewer was satisfied with the prototype build and experimental testing but, suggested that more unique points should be identified for this project, pointing to. "Rectifier board incorporates capacitive resolver" as an example. The reviewer also, requested and explanation of how eight fold power density increase can be achieved here.

**Reviewer 4**

This reviewer cited a need to outline the plan to achieve the projects targets for power levels and cost.

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

**Reviewer 1**

This reviewer believed that achieving the power levels and cost are critical to future applications.

**Reviewer 2**

This reviewer pointed out that elimination of rare-earth (RE) material is consistent with the DOE targets.

**Reviewer 3**

This reviewer said that the project's focus would help develop key technology differences that could be exploited by industry.

**Reviewer 4**

This reviewer found that this project one is the most meaningful project for industry that the reviewer has seen this year. Wound-field synchronous machines and induction machines are important for traction applications. It is relevant to VTO objectives.

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

**Reviewer 1**

This reviewer said that the resources are sufficient for the project scope

**Reviewer 2**

This reviewer found the resources to be sufficient and did not see any issues.

**Reviewer 3**

This reviewer suggested that perhaps more resources are needed to address the project plan and goals.

**Reviewer 4**

This reviewer believed that the scope of this project needs to be broadened to encompass testing over the full operating range. The cost needs to be thoroughly understood for industry to take advantage of the technology

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

***Presenter***

Jagadeesh Tangudu, United Technologies Research Center

***Reviewer Sample Size***

A total of four reviewers evaluated this project.

***Project Relevance and Resources***

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

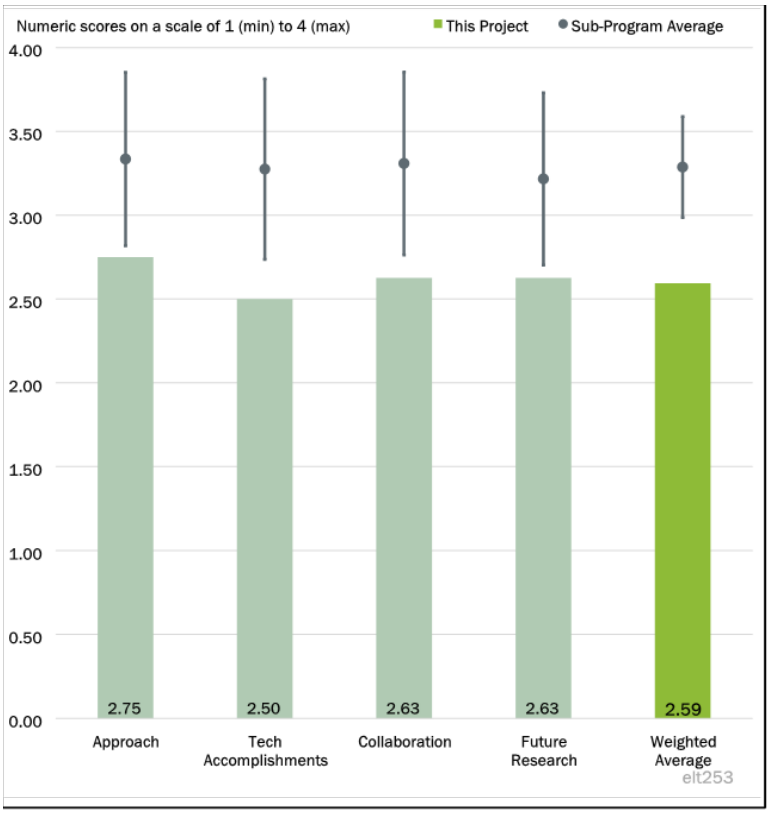


Figure 4-21 - Presentation Number: elt253 Presentation Title: Motor with Advanced Concepts for High-Power Density and Integrated Cooling for Efficiency Machine Principal Investigator: Jagadeesh Tangudu, United Technologies Research Center

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

**Reviewer 1**

This reviewer said that the overall approach is well designed and on track.

**Reviewer 2**

This reviewer found that the main novelty seems to be related to the in-slot cooling, the details of which are not very clear, according to the reviewer.

**Reviewer 3**

This reviewer believed that the project is exploratory in nature only with focus on design and design trade-offs. The reviewer was concerned that no reliability/durability, or detailed cost evaluation is being performed.

**Reviewer 4**

This reviewer believed that the approach used in this project does not seem to be helpful for the high-specific-power goals, because most likely, a FSCW-SPM machine spinning at greater than 20,000 revolutions per minute requires retaining sleeves, which increase the air gap length and losses. Second, in-slot embedded

cooling is only dealing with stator winding losses. There is no plan for stator core, rotor cooling, and power electronics cooling. The reviewer also asked what is the name of the "low loss electric steel" and whether it has lower permeability or higher cost. The reviewer found that the approaches here are very ambiguous.

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

**Reviewer 1**

This reviewer believes that the project is on track and expressed interest in seeing the final results.

**Reviewer 2**

This reviewer said that the work that has been accomplished based on the project plan is good but the project though is too limited in scope to help the auto industry commercialize this technology.

**Reviewer 3**

This reviewer was disappointed that the details of the analysis performed especially the thermal and structural have not been shared and found it not clear what type of life analysis has been performed.

**Reviewer 4**

This reviewer said that it is well-known that SPM work is vulnerable under a demagnetizing field and that FSCW machines are prone to loss. In order to accommodate non-heavy RE material, low operating temperatures (less losses/better TMS) and better protection, e.g., using interior permanent magnets (IPM) are required, raising the question for the reviewer of why FSCW-SPM is selected specifically for vehicle powertrain for this project. Further, based on the contents of the slides and giving the fact that it was funded in FY 19, the reviewer had concerns about the project timeline. Although it is claimed that everything is on track, according to the reviewer, many things are missing here: detailed final design, demagnetization analysis, a clear cooling design, etc. The presenter mentioned that there were supply chain issue, shipping and other delays. But, the reviewer asks why other presenters and their projects were not hit so badly. Also, the reviewer found no details (data or figures) about the latest design analysis.

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

**Reviewer 1**

This reviewer said that the project is on track.

**Reviewer 2**

This reviewer said that a vehicle OEM should be added as a participant.

**Reviewer 3**

This reviewer said that the level of collaboration is not very clear, especially when it comes to the integration details of the motor and inverter,

**Reviewer 4**

This reviewer said that the team (Raytheon Technologies and John Deere) looks good. But, based on the presentation, the reviewer was not sure what has been really accomplished so far.

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

**Reviewer 1**

This reviewer said that the project is in its final phase;

**Reviewer 2**

This reviewer said that verification testing will help confirm the analytical predictions.

**Reviewer 3**

This reviewer said that it is not clear from the materials presented what the next steps are, apart from that testing will be completed, and a report filed.

**Reviewer 4**

This reviewer found that no proposed future research was explained during the presentation.

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

**Reviewer 1**

This reviewer found the project to be critical to improving the electrification portfolio for cost and performance

**Reviewer 2**

This reviewer said that, directionally, a few aspects of the proposed approach can help meet the DOE targets.

**Reviewer 3**

This reviewer expressed a lack of confidence that this work has enough information points to make it useful for industry.

**Reviewer 4**

This reviewer said that the project has high relevance to the VTO subprogram objectives.

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

**Reviewer 1**

This reviewer said that the project is on track.

**Reviewer 2**

This reviewer said that the resources are sufficient based on the project scope.

**Reviewer 3**

This reviewer said that the resources are sufficient for this project.

**Reviewer 4**

This reviewer said that the project needs to develop a detailed understanding of the technology for it to be useful.

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

***Presenter***

Jim Gafford, University of North Carolina at Charlotte

***Reviewer Sample Size***

A total of three reviewers evaluated this project.

***Project Relevance and Resources***

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

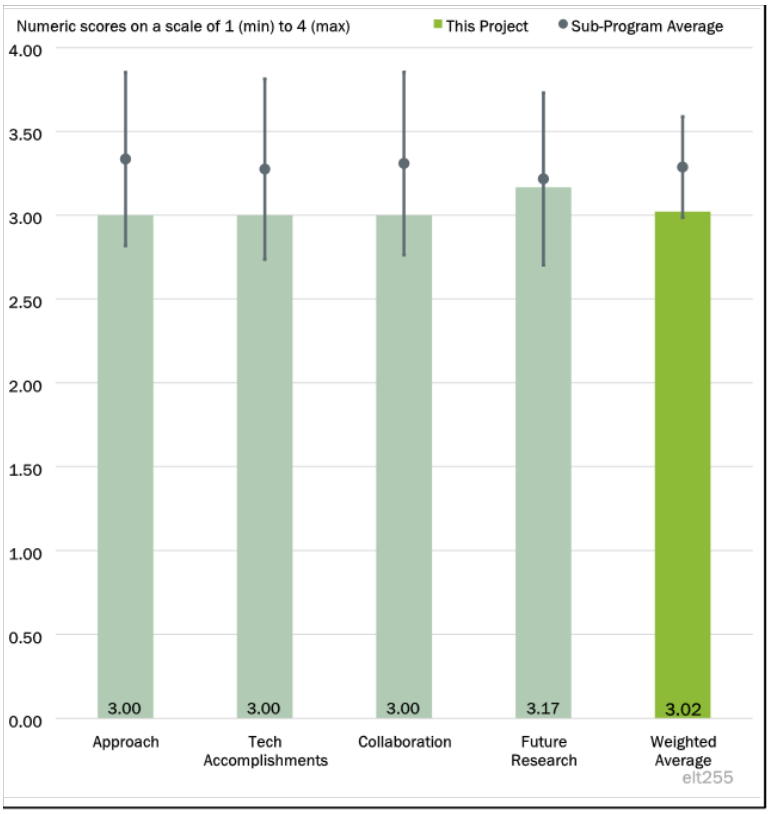


Figure 4-22 - Presentation Number: elt255 Presentation Title: Cost-Effective, Rare-Earth-Free, Flux-Doubling, Torque-Doubling, Increased Power Density Traction Motor with Near-Zero Open-Circuit Back-Electromagnetic Field and No-Cogging Torque Principal Investigator: Jim Gafford, University of North Carolina at Charlotte

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

**Reviewer 1**

This reviewer said that the approach is well thought out.

**Reviewer 2**

This reviewer said that the project tasks are appropriate and reasonable. The level of the build and testing to be performed leaves many industry questions unanswered. As an exploratory project, it is a good step forward, but it has major gaps when considering the purpose of accelerating vehicle technology deployment to benefit consumers.

**Reviewer 3**

This reviewer found that the novelty of the proposed approach is not very clear; even though it was mentioned that an IPM machine was used as a baseline, no details or quantitative comparisons were provided; and the details of what leads to such high inverter power density were not shared.

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

**Reviewer 1**

This reviewer found that good test results had been achieved with promising applications.

**Reviewer 2**

This reviewer believed that, based on the scope of work, the progress has been excellent. This project, however, is missing essential work to provide commercialization value to industry and to overcome barriers, including, for example, the scaling of the motor to traction power level, testing for durability/reliability, and cost analysis.

**Reviewer 3**

This reviewer considered that, compared to the accomplishments of previous years, the FY 2022 accomplishments seem incremental. More test results and characterization of the motor and inverter are needed.

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

**Reviewer 1**

This reviewer said that the collaborators are well respected and are actively participating but would have liked to see a vehicle manufacturer as a partner.

**Reviewer 2**

This reviewer found the project to be well coordinated.

**Reviewer 3**

This reviewer found a clear definition of roles among team members.

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

**Reviewer 1**

This reviewer expressed interest in seeing the test results of the dynamometers and an economic analysis.

**Reviewer 2**

This reviewer believed that more test results are needed

**Reviewer 3**

This reviewer said that the proposed future work, based on the scope that this project has, is reasonable and would be meaningful if the project were followed by more extensive development and testing of the motor.

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

**Reviewer 1**

This reviewer believed that the project is critical to improving power density and cost.

**Reviewer 2**

This reviewer said that, if successful, the project can satisfy some of the DOE targets.

**Reviewer 3**

This reviewer found that technical relevance of this project exists

But without the further work to understand reliability/durability, full operating testing, and cost analysis, this work will have limited or no commercial opportunity.

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

**Reviewer 1**

This reviewer found the project to be on track.

**Reviewer 2**

This reviewer said that the resources are sufficient based on the project scope

**Reviewer 3**

This reviewer found that the project itself has merit, but its scope is too limited.

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

### *Presenter*

Mike McHenry, Carnegie Mellon University

### *Reviewer Sample Size*

A total of four reviewers evaluated this project.

### *Project Relevance and Resources*

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

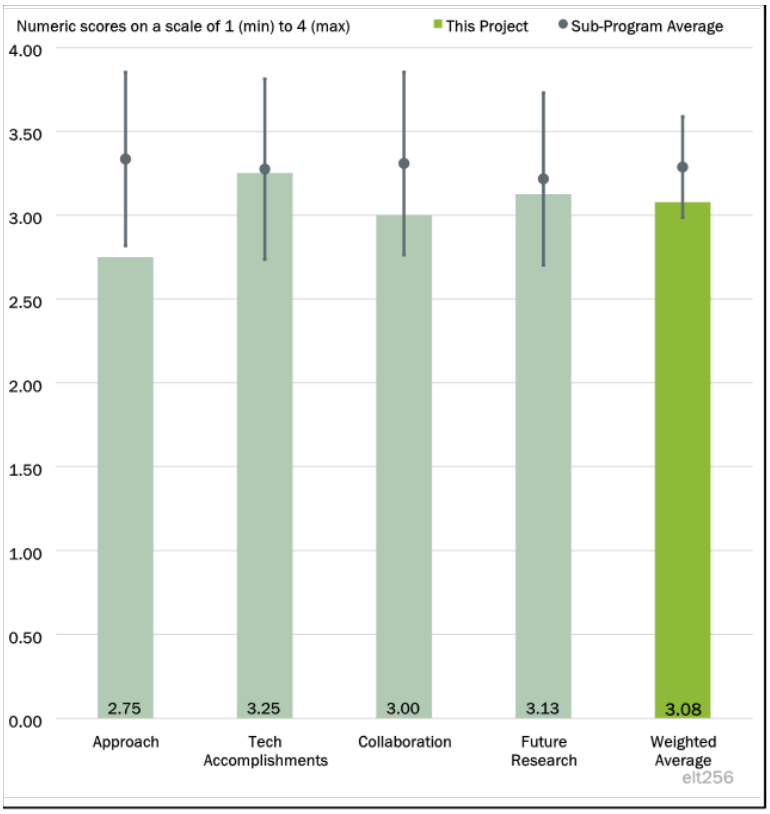


Figure 4-23 - Presentation Number: elt256 Presentation Title: Amorphous Metal Ribbons and Metal Amorphous Nanocomposite Materials Enabled High-Power Density Vehicle Motor Applications Principal Investigator: Mike McHenry, Carnegie Mellon University

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

**Reviewer 1**

This reviewer believes that the project is systematically addressing the open questions.

**Reviewer 2**

This reviewer commented that material suppliers/developers should be included as partners in this as well.

**Reviewer 3**

This reviewer found that the barriers and technical targets listed on Page 2 are inadequate. There is no definition or explanation of the targets; just a litany of topics that are developed further within the presentation. The reviewer found it unclear whether the timeline is reasonably planned since no time plan for work is shared other than a high level review of a couple milestones. Furthermore, according to the reviewer, the listing of future work would indicate that the project will not be completed.

**Reviewer 4**

This reviewer found that the baseline used to claim an eight-fold improvement in power density is not suitable for traction applications; the assumed very high switching frequencies do not take into consideration the impact on the motor insulation life; and the proposed motor topology is fairly complicated and will end up being an expensive option.

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

**Reviewer 1**

This reviewer said that the project has achieved all technical milestones and made very good progress towards solving the main challenge.

**Reviewer 2**

This reviewer said that the progress has been systematic, addressing manufacturing and analysis of sample material for performance and mechanical properties.

**Reviewer 3**

This reviewer said that the specific accomplishments for the worked performed is detailed well. The manufacturing slides provide especially good insights. The reviewer believed that it would be helpful if there were an explanation or discussion of how the accomplishments would specifically lead to the desired motor performance including how the FEA proves motor success? The reviewer found it unclear on Slide 18 if the stress calculations indicate that the motor will fail and asked what is the backup plan if it were to fail.

**Reviewer 4**

This reviewer suggested that a quantitative comparison of the proposed motor performance, including the AMR, against a well-defined set of specifications or baseline for traction applications should be included.

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

**Reviewer 1**

This reviewer found a very good listing of collaboration partners and the work performed but asked whether the North Carolina State University motor testing will be completed in time.

**Reviewer 2**

This reviewer found great collaboration, but would have preferred to see a vehicle manufacturer involved.

**Reviewer 3**

This reviewer said that, while the designed collaboration has really worked, the scope needs to be broadened to include metal alloy suppliers, epoxy suppliers and other material chemistry developers.

**Reviewer 4**

This reviewer said that there seems to be a good level of collaboration among partners.

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

**Reviewer 1**

This reviewer found that the proposed future research is clearly outlined with actionable steps and path forward.

**Reviewer 2**

This reviewer believed that the project has an excellent plan.

**Reviewer 3**

This reviewer said that more comprehensive motor performance verification testing is needed.

**Reviewer 4**

This reviewer believed that more future work challenges should have been listed and asked: 1) Why a roadmap of standard safety factors is needed for completion of this project; and whether the testing at NC State will correlate FEA and tensile strength results to actual motor performance.

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

**Reviewer 1**

This reviewer said that improved soft magnetic materials can be helpful in meeting the DOE objectives

**Reviewer 2**

This reviewer believed that it is important to research these materials and show how they can be successfully manufactured to achieve VTO motor objectives.

**Reviewer 3**

This reviewer said that materials are critical to meeting DOE targets.

**Reviewer 4**

This reviewer said that the project will help meet energy efficiency targets.

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

**Reviewer 1**

This reviewer said that the project is properly resourced.

**Reviewer 2**

This reviewer would have liked to see follow-on work sponsored for commercialization.

**Reviewer 3**

This reviewer was unable to determine this, saying that the budget for the project was not listed.

**Reviewer 4**

This reviewer said that budget information was not included.

**Presentation Number: elt258**
**Presentation Title: Grid-Enhanced, Mobility-Integrated Network Infrastructures for Extreme Fast Charging (GEMINI-XFC)**
**Principal Investigator: Andrew Meintz, National Renewable Energy Laboratory**

***Presenter***

Andrew Meintz, NREL

***Reviewer Sample Size***

A total of three reviewers evaluated this project.

***Project Relevance and Resources***

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

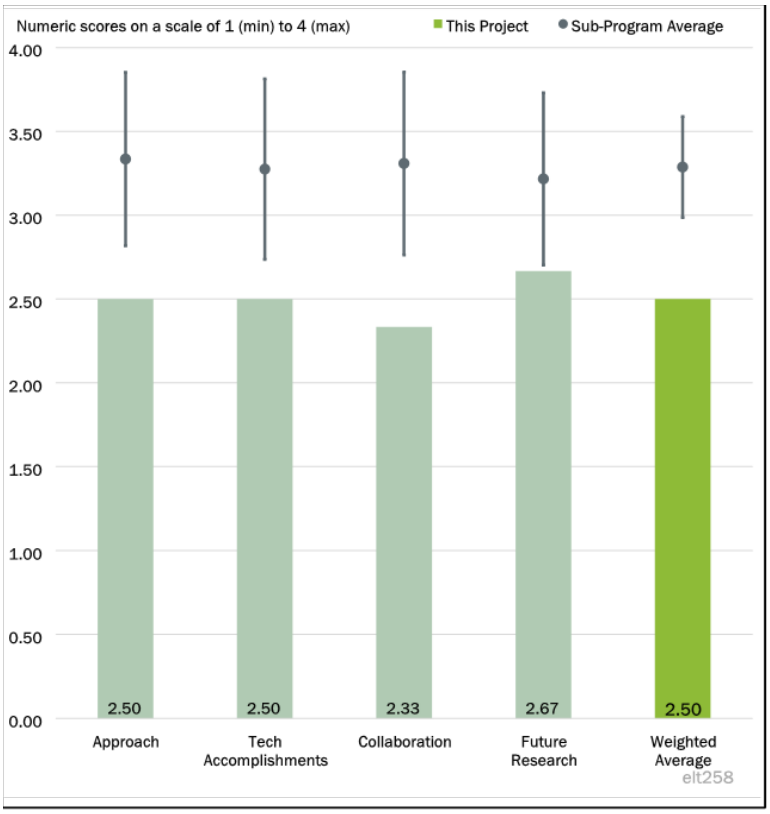


Figure 4-24 - Presentation Number: elt258 Presentation Title: Grid-Enhanced, Mobility-Integrated Network Infrastructures for Extreme Fast Charging (GEMINI-XFC) Principal Investigator: Andrew Meintz, National Renewable Energy Laboratory

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

**Reviewer 1**

This reviewer said that the technical barriers are identified and the timeline is reasonable. However, it is not clear how simulations only will truly address the technical barriers. The modeling data need to be compared against real data.

**Reviewer 2**

This reviewer found that, because the project focus is on one densely populated area, it is not clear how the data apply to other locations. This study is based on SFD and MUD and the majority of use is AC L1. There are no data on commercial use of XFC that will certainly not have this proportion of AC L1.

**Reviewer 3**

This reviewer said that no information was provided in the presentation on the number of electric vehicles involved, the percentage that were ride-hailing, the percentage of the total charging power demand served by extra fast charging, what thresholds constituted high EV adoption, and other variables. Second, the choice of the San Francisco Bay area to study the interaction between power grid and extra-fast charging infrastructure was poor because it is not representative (i.e., typical) of most U.S. cities. San Francisco and the Silicon Valley

are geographically isolated because they are on a peninsula accessed by bridges and ferries, which constitute traffic bottlenecks. Also, transit usage is high in San Francisco and there is a reverse commute that prevails between San Francisco and the Silicon Valley (San Jose, Santa Clara, Milpitas, etc.).

The definition of the objective, "Identify how XFC will support transportation with evolving mobility patterns and very high EV adoption levels" is very ambiguous, so it is difficult to determine accomplishments. Likewise, the same applies to "As impacts of widespread uncoordinated XFC of passenger vehicles on distribution networks."

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

**Reviewer 1**

This reviewer said that the project appears to be on track with its plan.

**Reviewer 2**

This reviewer believed that the technical accomplishments and progress thus far are unimpressive. According to the reviewer, the data collected do not make a bit of difference in what we already know: that coordination will be required among the charging infrastructure, grid, and vehicles. It is sad to see only six months devoted to the control strategies for coordination because this coordination is the strategic centerpiece of the entire project and what makes this project worthwhile.

**Reviewer 3**

This reviewer stated that commercial vehicles that have local routes along with other vehicles passing through need to be evaluated for XFC in this project.

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

**Reviewer 1**

This reviewer pointed out that the team is comprised of only national labs. Since the team was modeling a specific geographic area it should have included the electric utility serving that area. Further, it should have included fleet operators since they would be the most likely to change behavior based on signals.

**Reviewer 2**

This reviewer stated that the milestones need to show what NREL and Lawrence Berkeley National Laboratory is performing. These roles are not identified.

**Reviewer 3**

This reviewer felt that collaboration and coordination across the project team was extremely limited and thus, disappointing; it was limited to the national laboratories. No other public or private organizations were incorporated as partners. Unfortunately, organizations involved in traffic modeling, such as the metropolitan planning organization (the Metropolitan Transportation Commission) for the San Francisco Bay area were not made partners and neither was a utility (such as Pacific Gas and Electric) made a partner.

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

**Reviewer 1**

This reviewer suggested that an economic analysis should be included, particularly if infrastructure upgrades are evaluated.

**Reviewer 2**

This reviewer said that the focus needs to include EV's with longer range, that may not charge as often. Including light-duty and commercial vehicles data in Sept 2022 will also change the results and should provide a more complete analysis of XFC requirements.

**Reviewer 3**

This reviewer noted that the project has only another six months to be completed. The two major tasks that are remaining are coordination and control strategies in Hierarchical Engine for Large-scale Infrastructure Co-Simulation (HELICS) and assessment of impact on distribution networks. The principal investigator failed to describe in detail, examples of control strategies, assumptions for control strategies, and the baselines that would be used for control strategies. With respect to distribution networks, the team should have clarified in its presentation that these are not city-wide or region-wide distribution networks but on-site distribution networks. The reviewer believed that the assessment of the localized impact on site distribution networks is a trivial, insignificant task or minor detail that could have been deferred or omitted.

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

**Reviewer 1**

This reviewer said that the project supports the objectives.

**Reviewer 2**

This reviewer pointed out that the project team has indicated that passenger cars may use more AC L1 than XFC in highly populated areas but their effect needs to be assessed in other less densely populated cities.

**Reviewer 3**

According to this reviewer, this project seems relevant to only the area of analysis; it does not have any impact on batteries, electrification, energy-efficient mobility systems and advances in materials. Even in the area of analysis, it seems academic rather than practical.

Most important, the reviewer said, is the fact that the project does not make a cogent case for extra fast charging, especially of electric passenger vehicles. Because the overwhelming majority of electric passenger vehicles are or will be used for commuting between home and work, extra fast charging is unnecessary and can simply be replaced by charging at home, a much more cost-effective option with the least impact on the electric power grid. Ride-hailing electric passenger vehicles and light-duty electric package/delivery vehicles are the most likely sectors to use extra fast charging, but these constitute a minority

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

**Reviewer 1**

This reviewer said that the project should include other partners, particularly entities that would benefit from the model.

**Reviewer 2**

This reviewer said that the modeling tools are well defined, but it is not clear how to include modeling for extended range cars and added use for commercial vehicles.

**Reviewer 3**

This reviewer believed that the project costs for modeling are excessive in light of the fact all the models used for this project have been already developed or programmed. There was no need to develop, test and debug new models for this project.

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

***Presenter***

Marcus Malinosky, Daimler Trucks North America

***Reviewer Sample Size***

A total of four reviewers evaluated this project.

***Project Relevance and Resources***

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

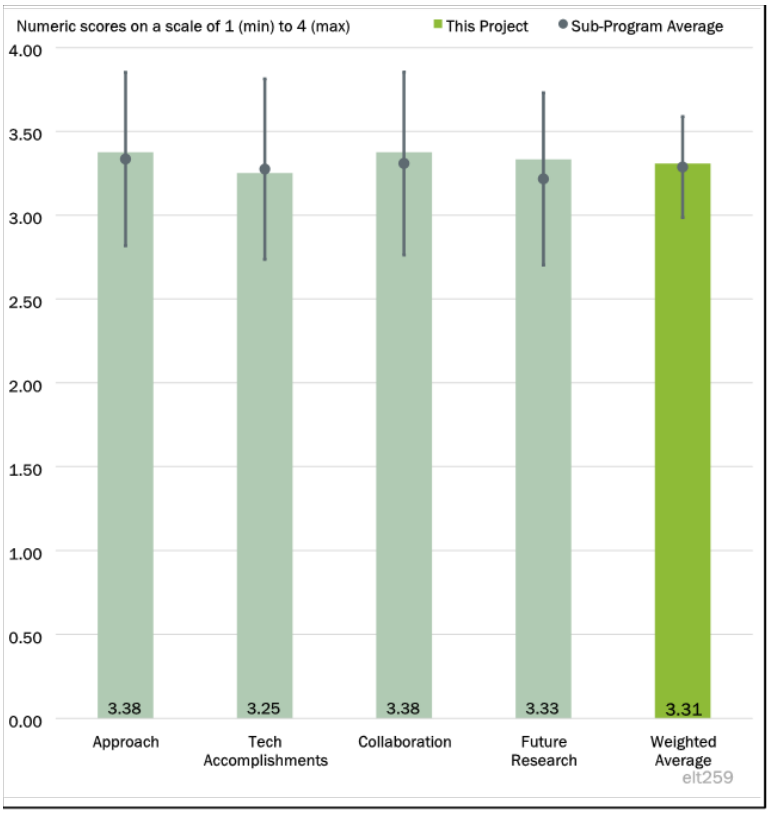


Figure 4-25 - Presentation Number: elt259 Presentation Title: Development and Commercialization of Heavy-Duty Battery Electric Trucks Under Diverse Climate Conditions Principal Investigator: Marcus Malinosky, Daimler Trucks North America

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

**Reviewer 1**

This reviewer said that the approach is really nice and is looking forward to the additional vehicle deployment testing.

**Reviewer 2**

This reviewer found the approach to be somewhat difficult to evaluate, since the presentation focused on the managerial details about meeting goals and milestones. One feature that the reviewer thought was especially good was the postulation of several duty cycles that showed how careful scheduling could enable an electric truck to travel many more miles in a day than its range on a full charge. This enabled a sensible design, although the reviewer believes that the cost of a 10,000 lb. battery is likely to make the design somewhat impractical.

**Reviewer 3**

This reviewer said that the team is doing a good job of making the technology ready for production.

**Reviewer 4**

his reviewer said that the two barriers that this project intended to overcome were to extend the range for all-electric medium- and heavy-duty trucks to 250 miles per day and to make such trucks viable for manufacture by large volume companies. The project has demonstrated that the range of 250 miles per day has been attained and has started commercial series production this year.

The timeline was reasonably planned. The principal investigator reports that 80% of the work has been accomplished. This is reasonable, considering that this project has a duration of 40 months of which 34 months have passed. So, one would expect that, working at a steady rate, 34/40 or 85% of the project would be accomplished.

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

**Reviewer 1**

This reviewer said that the cold weather testing was revealing and important and a big milestone. Final deployment-level testing will be critical to prove every in the end.

**Reviewer 2**

This reviewer found it impressive that the team managed to remain on schedule and accomplish several builds when others were severely delayed by supply chain problems but that it would have been much more informative if the presentation gave some clue as to the improvements made from Truck A to B to C...

**Reviewer 3**

This reviewer said that the project showed good progress with one exception. The exception is that it failed to corroborate improved performance over the baseline eCascadia in the following areas: increased fuel efficiency of 2.0 kWh/mile; increased battery capacity up to 550 kWh; and reduced curb weight down to 20,000 lbs. The principal investigator needs to show whether these three objectives, as indicated in Slide 3, were actually accomplished or are still in progress And, if they are still in progress, what is the extent (percentage) accomplished.

**Reviewer 4**

This reviewer found that the team is doing a good job at meeting the target that has been set, which is a 250 mile range. The reviewer would have preferred, however, for the team to have chosen a more difficult target to meet, i.e., a higher range. Volvo currently offers a tractor with up to 275 miles of range. The reviewer believes that DOE should fund projects that stretch the limits of what is currently feasible, rather than replicate something that is already available.

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

**Reviewer 1**

This reviewer said that good collaboration with partners was described.

**Reviewer 2**

This reviewer believed that the PIs had assembled an excellent team that covered the spectrum of required skills. There was coordination in that the designers had an understanding of the needs of the users before they designed the truck system.

**Reviewer 3**

This reviewer noted that Daimler has partnered with two end-user entities for fleet operations: Meijer (a grocery store chain in the Midwest) and United Parcel Service and with one regulatory agency: SCAQMD. The two end-user entities are more than qualified to test the operations of the production and demonstration vehicles. SCAQMD is renowned for enforcing rigorous regulatory requirements for medium- and heavy-duty vehicles.

**Reviewer 4**

This reviewer reported that the partners are ready to put the trucks in the field once they are ready. Not much was shared, however, according to the reviewer, about the partners, since they did not have the trucks yet.

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

**Reviewer 1**

This reviewer was looking forward to seeing the remaining results.

**Reviewer 2**

This reviewer pointed out that the plan is to demonstrate the trucks and collect data to validate the concept. The reviewer expressed interest in seeing a cost analysis as well, including any lost revenues from carrying around 10,000 pounds of batteries.

**Reviewer 3**

This reviewer believed that an interesting part of the future work should be to gather feedback from the partner organizations who will put the trucks in the field in order to learn and identify potential areas of improvement. The time allocated to that seems limited as trucks are currently being delivered and the project ends by year end.

**Reviewer 4**

This reviewer pointed out that the project has only six months to complete.

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

**Reviewer 1**

This reviewer believes that the project is highly relevant work with potential for major carbon neutral impact.

**Reviewer 2**

This reviewer said that the project is relevant in that it helps moving towards a decarbonized transportation sector.

**Reviewer 3**

This reviewer said that this is another project that helps break down barriers to electrification of the entire transport sector, and so is totally in line with the ELT goals.

**Reviewer 4**

This reviewer said that the project supports the VTO subprogram areas of analysis, battery, electrification, and energy-efficient mobility systems (weight reduction). This project supports the electrification of heavy-duty vehicles, and, thus, reduced reliance on fossil fuels and reduced emission of greenhouse gases. An affordable, commercially available electric-battery medium- and heavy-duty truck is definitely needed to fill a gap in the surface transportation sector.

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

**Reviewer 1**

This reviewer said that the resources seem sufficient.

**Reviewer 2**

This reviewer said that the resources allocated seem appropriate despite the difficulty of judging without any accounting breakdown.

**Reviewer 3**

This reviewer said that there has been no indication that the project has encountered resource problems. The resource problems are predominantly related to delays due to supply-chain interruptions during the pandemic.

**Reviewer 4**

This reviewer found that the resources appear sufficient overall. A higher portion of the funding and effort could have been on the analysis of the trucks in the field. As this is a new technology, analysis of field testing should be key to help OEMs make future improvement to their proposed solutions. Documenting field testing would also increase visibility of the technology and help increase customer acceptance.

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

### *Presenter*

Jian Li, Volvo, and William Northrop, University of Minnesota

### *Reviewer Sample Size*

A total of four reviewers evaluated this project.

### *Project Relevance and Resources*

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

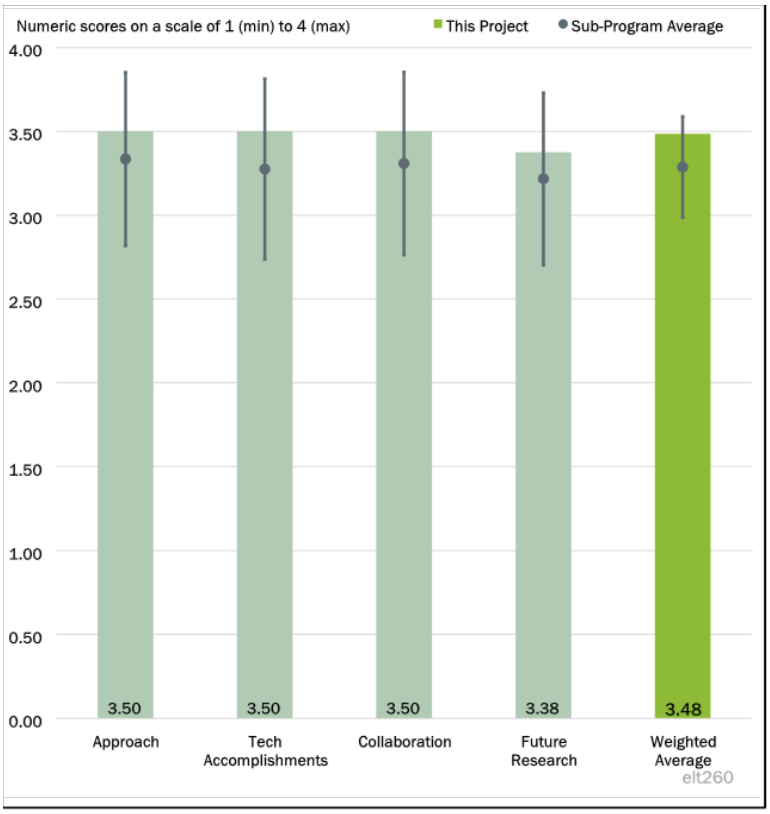


Figure 4-26 - Presentation Number: elt260 Presentation Title: Improving the Freight Productivity of a Heavy-Duty, Battery Electric Truck by Intelligent Energy Management Principal Investigator: Teresa Taylor, Volvo

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

**Reviewer 1**

This reviewer said that the project tackles the goal of EV freight energy efficiency with a number of techniques, which is appropriate given the uncertainties involved (load, driver behavior, environmental variability).

**Reviewer 2**

This reviewer found the three different techniques to estimate mass (detailed to regression) interesting. Load will drive a large charge in vehicle range. Eco routing is likely more important to EVs than to internal combustion engines and this approach to allowing time to be valued along with efficiency (miles kWh) is good for user flexibility.

**Reviewer 3**

This reviewer found that it is an interesting project with a good approach.

**Reviewer 4**

This reviewer found it useful to have included some modeling in the effort, but that actual on-road experience is what will really matters. The reviewer has concern that the participants are more interested in using elegant tools than in performance. If preliminary data show that route optimization only results in a few percent savings, perhaps that feature should be eliminated.

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

**Reviewer 1**

This reviewer said that several techniques for energy estimation and route selection based on optimal energy consumption have been demonstrated.

**Reviewer 2**

This reviewer reported having seen very similar math and approaches to eco-routing. This yields its own version and the attribute list looks complete. It would be useful to see a distribution of miles/kWh or similar energy efficiency for all routes and types as the project completes if that information is stored and collected. The reviewer would like to see if there any balance of lost time from having to Eco route trips vs. lost time if routes are not completed from lack of battery energy to complete and if some level of buffer need between eco benefits and time can be determined.

**Reviewer 3**

Very good progress is being made.

**Reviewer 4**

This reviewer expressed being a bit concerned about the siting of charging infrastructure. The example in the slides had unconstrained costs. But, in reality, EVSE can be expensive. Since the team is obviously big on modeling and optimization, the reviewer suggests that it consider siting EVSE in the overall most cost-effective way, rather than where it is optimum for the trucks. Getting the trucks to the users was a big accomplishment.

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

**Reviewer 1**

This reviewer found excellent collaboration between academic and industrial partners with each doing what it does best.

**Reviewer 2**

This reviewer was impressed with all of this project's teams. Each team includes a truck manufacturer, an academic institution to do the hard calculations and analysis, and actual real-world users to demonstrate that all of the calculations and theoretical ideas actually work where the rubber meets the road.

**Reviewer 3**

This reviewer found nothing to add, saying that the listed partners completed the required tasks as planned.

**Reviewer 4**

This reviewer said that there is good collaboration amongst the project team members.

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

**Reviewer 1**

This reviewer said that the next steps are appropriate for successful demonstration.

**Reviewer 2**

This reviewer expressed interest in seeing the data at the end of this project. Specifically, the reviewer is interested in whether the trucks meet their efficiency and range goals, how the costs/total cost of ownership will compare to hybrid or other designs, and whether any glitches are observed during operation.

**Reviewer 3**

This reviewer found the future research plans good

**Reviewer 4**

This reviewer said that the project does not list any FY2023 funding, but proposed FY2023 work. The proposal looks good as it exercises the tools that were created to create useable data for planning.

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

**Reviewer 1**

This reviewer said that the project develops necessary technology to maximize electric truck range, given the challenges of onboard energy storage, making it relevant to the electrification goals of VTO.

**Reviewer 2**

This reviewer predicted that the project will help prove that electrification of heavy-duty trucks can be a practical reality.

**Reviewer 3**

This reviewer said that route planning and energy conservation to improve the EV experience fits within the objectives.

**Reviewer 4**

This reviewer said that the project is very relevant to the overall VTO objectives.

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

**Reviewer 1**

This reviewer said that the project appears to be sufficiently funded, with good progress.

**Reviewer 2**

This reviewer said that the project is listed as completing. Funding and Team Resources are presented as being sufficient to close out or follow-on if new funding is awarded.

**Reviewer 3**

This reviewer said that the resources appear to be sufficient.

**Reviewer 4**

This reviewer said that the resource question is very hard to answer without seeing a budget But nothing stands out as unusual.

**Presentation Number: elt261**
**Presentation Title: High-Efficiency Powertrain for Heavy-Duty Trucks using Silicon Carbide Inverter**
**Principal Investigator: Steve Peelman, Ricardo**

***Presenter***

Steve Peelman, Ricardo

***Reviewer Sample Size***

A total of three reviewers evaluated this project.

***Project Relevance and Resources***

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

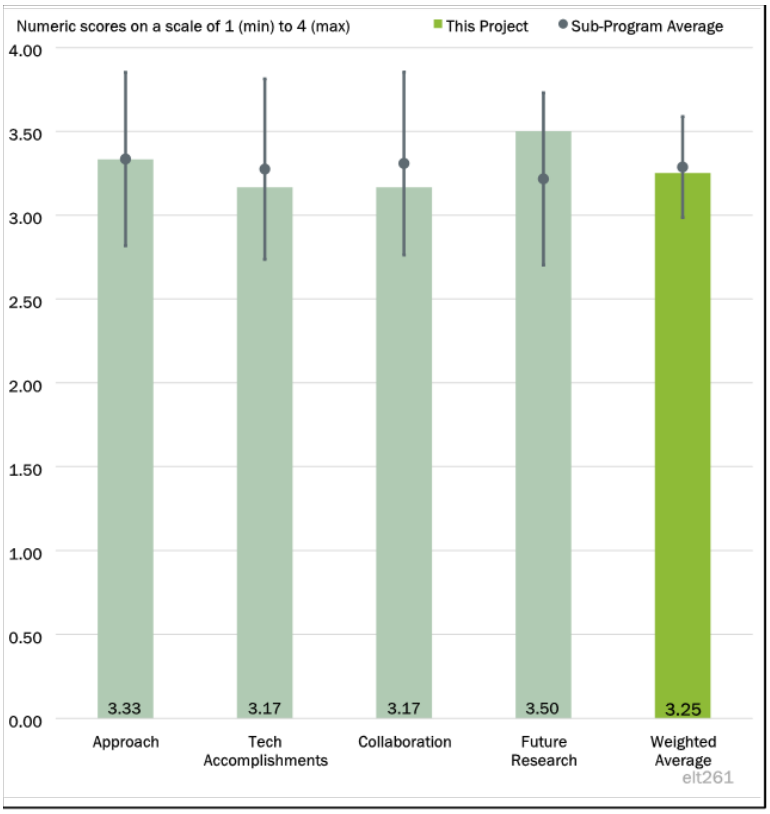


Figure 4-27 - Presentation Number: elt261 Presentation Title: High-Efficiency Powertrain for Heavy-Duty Trucks using Silicon Carbide Inverter Principal Investigator: Steve Peelman, Ricardo

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

**Reviewer 1**

This reviewer said that the project approach is excellent.

**Reviewer 2**

This reviewer said that developing an A-sample of a SiC inverter to assess technology feasibility followed by fabrication of eighty units of B-sample of SiC inverter for performance evaluations including conformation of inverter efficiency of 98.5% is a logical and appropriate approach taken by the project team. The B-sample allowed for creation of the SiC inverter ecosystem and all necessary know-how for Ricardo to proceed.

The reviewer believed that the inverter efficiency needs to be re-measured at elevated inverter coolant temperatures and ambient temperatures around the inverter because, at 25°C ambient and 25°C coolant, 98.5% efficiency may not mean much for TransPower's real world application of the SiC inverter.

**Reviewer 3**

This reviewer said that the overall approach seems reasonable for achieving the stated objectives—specifically, going through first an A and then a B development cycle to produce an inverter satisfying the stated efficiency, power and power density targets, and subsequently demonstrating the developed inverter through in-use operation in a vehicle. Likewise, the approach for the current budget period seems appropriate i.e., completing

development and testing on the B-sample inverter and preparing for vehicle installation and testing. The reviewer would have liked to get a little more information on the rationale/source for the stated goals, for instance, whether these were defined by the funding call that awarded this specific project. In the Electrification Annual Progress Report, some of the ultimate goals called out for the Electric Drive Technologies Lab Consortium appear to be more aggressive than the goals called out for this project, so it would be good to better understand how those relate to each other along with to the current state of the art at the outset of the project. The reviewer also would have preferred for the milestone table to include the dates of the listed interim milestones.

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

**Reviewer 1**

This reviewer said that very good progress is being made.

**Reviewer 2**

This reviewer said that the presentation highlighted quite a few accomplishments and challenges that had to be overcome to achieve them. Key accomplishments included successful B-sample inverter development and operation at or above the target power level, and preparation of the Peterbilt truck for in-vehicle testing in the final year of the project. The presenter also provided a verbal update that, since the time when the slides were put together, the bench testing has now slightly exceeded the target 98.5% operating efficiency goal with power output exceeding 250 kW. The presenter also noted that the results are currently showing a roughly 44 kW/L energy density, but that the team has some modifications planned to hopefully exceed the 50 kW/L design target. The reviewer would like to see a consolidated table listing the full set of design targets and the project status against achieving each. As cost is certainly an important target, the reviewer would like to see this included as well, or at least to have an indication that this is something being discussed and reviewed with DOE to confirm commercial viability.

**Reviewer 3**

This reviewer said that the project tasks and milestone are tracking, including fabrication of B-sample of SiC inverter followed by testing with a power supply as a DC source. Hardware and software requirements have been developed for the SiC inverter. Power module thermal simulation has been completed. Current sensor performance has been evaluated for command (torque) tracking. B-sample CFD simulation for thermal performance has been completed. Functional samples of 250 kW SiC inverter has been fabricated and pictures showing internal details are included in the project report. SiC power devices are double pulsed and improved DC bus contributed (50%) to the 23% improvements in performance of SiC switches.

Vehicle level powertrain development work is in progress, which task is led by Meritor (TransPower Inc.).

This reviewer has a significant concern, which is that when the inverter is powered by the battery-pack, efficiency may not hold at 98.5%, particularly when the coolant temperature is nearly that of the coolant flowing through battery-pack if the batteries are liquid cooled and experience temperatures far above 25°C.

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

**Reviewer 1**

This reviewer found that there are some good collaborations.

**Reviewer 2**

This reviewer found, from the presentation, that it seems that the Ricardo, Meritor, and NC State sub-teams work effectively together, and that each adds value to the project in complementary ways. There is no direct national lab collaboration on the project, but, hopefully, the project team is keeping abreast of relevant advancements by the labs.

**Reviewer 3**

This reviewer found that good collaboration exists between Ricardo and Meritor. NC State University is effectively supporting inverter development work and testing of the inverter with power inductors used for experimental simulation of three-phase R-L load.

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

**Reviewer 1**

This reviewer noted that the immediate next steps for the project are to complete the suite of inverter tests along with inverter integration into the two Class 8 electrified trucks. The presenter indicated that dynamometer testing had gotten pushed back from the original schedule of June but that it is now planned for that to happen this July. The final planned phase for the project will be to complete high mileage accumulation during demonstration and to capture, analyze, and report on the collected data.

**Reviewer 2**

This reviewer said that the proposed future research is clearly defined and good.

**Reviewer 3**

This reviewer said that future research is outlined in the project report including dynomometer scale characterization, which could be a scenario close to a real-world application of the 250kW SiC inverter.

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

**Reviewer 1**

This reviewer said that the project is relevant to the Electrification Program goals to increase the efficiency and power density of inverters for electrified heavy-duty truck applications.

**Reviewer 2**

This reviewer said that the project is relevant and supports the VTO objectives.

**Reviewer 3**

This reviewer said that a high efficiency and high power SiC inverter is needed for US truck fleets for commercial operations of greater than 250 miles/day. This project advances this objective of DOE-VTO and, hence, research executed and technology development work underway in this project are quite relevant to the DOE-VTO roadmap and objectives.

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

**Reviewer 1**

This reviewer said that the resources appear to be adequate for the project, with DOE providing roughly 62% of the funding, and cost share from the project team covering the remainder.

**Reviewer 2**

This reviewer said that the resources appear to be sufficient.

**Reviewer 3**

This reviewer said that the project team has the necessary resources and technical expertise and know-how to successfully complete this project.

**Presentation Number: elt262**
**Presentation Title: Long-Range, Heavy-Duty Battery-Electric Vehicle with Megawatt Wireless Charging**
**Principal Investigator: Stan DeLizo, Kenworth**

***Presenter***

Stan DeLizo, Kenworth

***Reviewer Sample Size***

A total of three reviewers evaluated this project.

***Project Relevance and Resources***

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

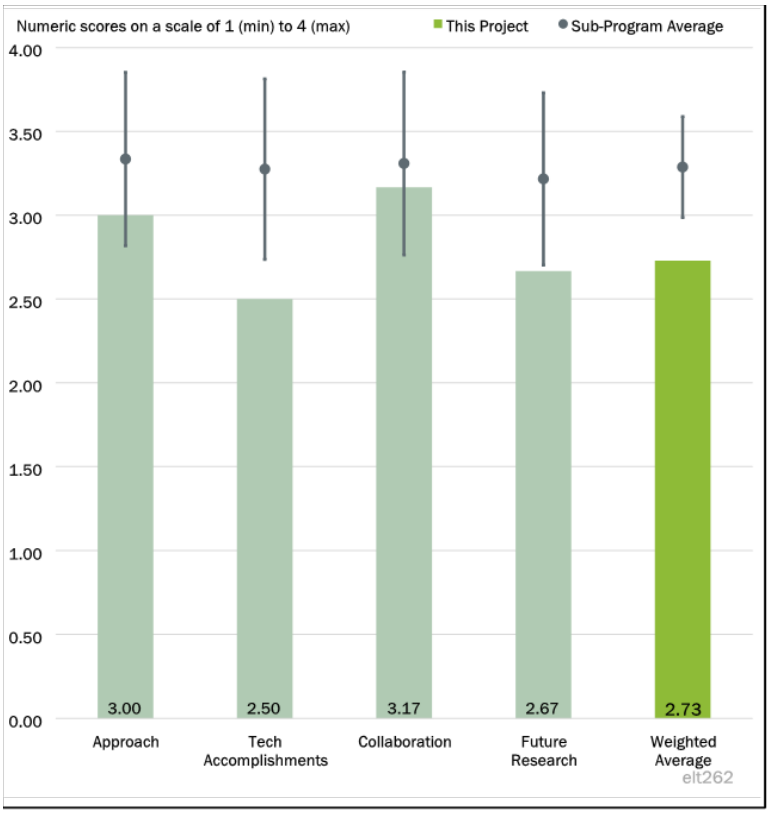


Figure 4-28 - Presentation Number: elt262 Presentation Title: Long-Range, Heavy-Duty Battery-Electric Vehicle with Megawatt Wireless Charging Principal Investigator: Stan DeLizo, Kenworth

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

**Reviewer 1**

This reviewer said that the project is ambitious and seems to have run into some execution difficulties. The goal of developing a MW charging system is challenging and worthwhile, but the reviewer found it surprising that the technical work for the wireless charger is led by Utah State University with WAVE supporting, rather than being a more collaborative effort.

**Reviewer 2**

This reviewer believed that the work plan was designed sensibly, with modeling preceding actual builds. With hindsight, orders for materials probably could have been placed sooner, but it's hard to predict pandemic-related supply-chain problems. The reviewer would have preferred for the presentation to have included more descriptive illustrations of how and where the charging system was to be constructed and attached. The reviewer wondered what would happen if a small dog wandered into the facility and would also like to see the charger demonstrated in torrential rain. The system is going to need extensive testing, when they finally put it together.

**Reviewer 3**

This reviewer said that the project is designed to mitigate potential issues but the risks are not necessarily due to the project design. Many issues are due to supply chain and pandemic issues and are likely to persist in the

short and medium term. Given the risk and that go/no-go decisions are already delayed, the reviewer believes that the project will continue to fall behind schedule.

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

**Reviewer 1**

This reviewer said that the project has suffered some setbacks due to component shortages and appears to have a plan in place to recover some lost time and address delays. Progress on the truck and battery development is good. The team should clarify the "expanded wireless pad testing from 125kW to 850kW" accomplishment on Slide 7, whether 850kW testing has commenced or does the slide mean only that an 850kW system will be build to test. The reviewer said that there was not a clear answer to this question during the review.

**Reviewer 2**

This reviewer believes that the team really needs to get an extension because it is behind on many milestones. Basically, it looks like the team completed all the modeling but ran into major delays due to supply-chain issues with parts for the actual build. The reviewer believes that modifications made to enable moving forward obviously were not enough to conquer the obstacles in their path.

**Reviewer 3**

This reviewer's big question with this project is competing technology. By the time this project, delayed as it is, achieves any project milestones, competing fuel cell technology may have evolved. The reviewer's other concern is the impact to the electric grid, in that any upgrades on the utility side may mitigate any speed to market advantage battery electric vehicles may have. Rather than continuing to extend project deadlines, the reviewer suggests that a better approach might be completely re-evaluate project timelines and then compare those timelines with fuel cell demonstration projects. Because the dates have been pushed out already, and given the pandemic and supply chain issues, any new timeline should take those factors into account. The reviewer questions whether it is still possible for the project to achieve its stated objectives before funding expires.

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

**Reviewer 1**

This reviewer said that the project has all of the key players onboard, from modeling and designing to building and testing, and to actual on-road application. To some extent, they work in series rather than in parallel, so they are serially collaborating. It is unclear to this reviewer how much interaction happened between the university partner and the actual truck operators.

**Reviewer 2**

This reviewer believes that the necessary partners to make the project successful are in place and collaborating. The reviewer finds it is somewhat surprising that WAVE is supporting rather than co-leading the wireless charger development.

**Reviewer 3**

This reviewer believes that there are many touchpoints, both virtual and in person, so collaboration is happening and this is not the project's weak point.

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

**Reviewer 1**

This reviewer said that the future work to get back on track and complete the project contains appropriate steps.

**Reviewer 2**

This reviewer said that the team's job now is pretty clear: to get the system built and running. Test results will be crucial. The reviewer would then like to see the team do a TEA to estimate the cost of a commercial system.

**Reviewer 3**

This reviewer reported not being confident that the project will achieve its objectives, given current industry challenges, at least in the funding timeframe.

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

**Reviewer 1**

This reviewer said that the project is a technology demonstration for the kind of charging that will be needed to make electrification practical in the medium and heavy duty truck sector.

**Reviewer 2**

This reviewer said that enabling of fast charging for heavy vehicles would enable electrification without huge expenditures for huge, heavy batteries. That would remove a big barrier to electrification of long-haul trucking.

**Reviewer 3**

This reviewer said that the project supports electrification.

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

**Reviewer 1**

This reviewer believed that the resources are sufficient and would not suggest adding additional resources, given there are industry challenges that added resources to the project won't overcome.

**Reviewer 2**

This reviewer believes that this question is always impossible to answer meaningfully without any detailed accounting for the budget. But resources seem reasonable.

**Reviewer 3**

This reviewer believes that the project needs more resources to accelerate the project to completion.

**Presentation Number: elt263**
**Presentation Title: Low-Cost Rare-Earth-Free Electric Drivetrain Enabled by Novel Permanent Magnets, Inverter, Integrated Design and Advanced Thermal Management**
**Principal Investigator: Ayman El-Refaie, Marquette**

***Presenter***

Ayman El-Refaie, Marquette

***Reviewer Sample Size***

A total of four reviewers evaluated this project.

***Project Relevance and Resources***

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

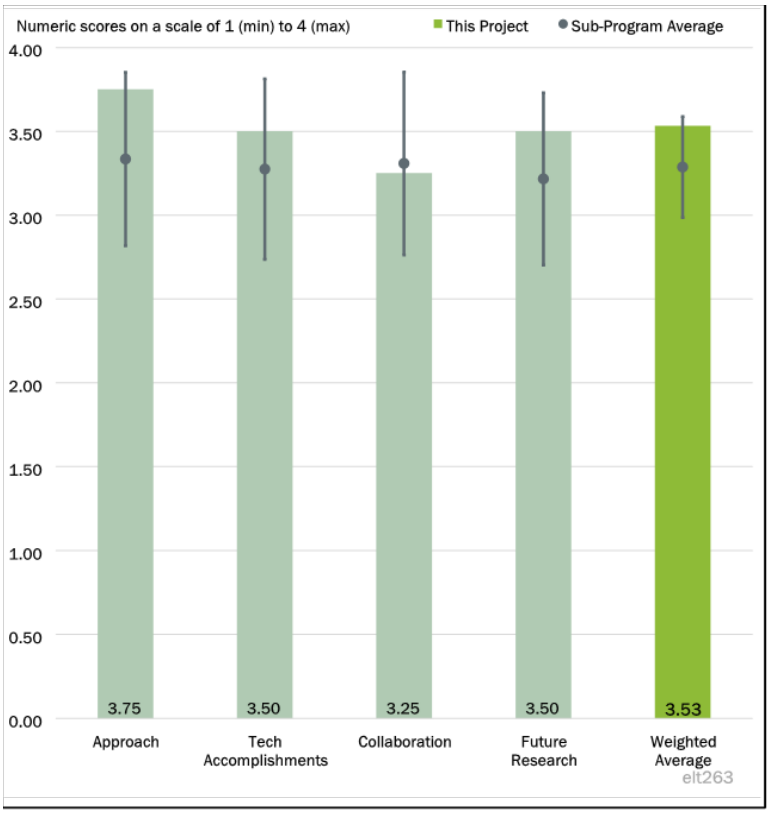


Figure 4-29 - Presentation Number: elt263 Presentation Title: Low-Cost Rare-Earth-Free Electric Drivetrain Enabled by Novel Permanent Magnets, Inverter, Integrated Design and Advanced Thermal Management Principal Investigator: Ayman El-Refaie, Marquette

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

**Reviewer 1**

This reviewer said that, so far, the approach is well planned and detailed

**Reviewer 2**

This reviewer believed that an appropriate development process is being used and that a thorough analysis has been done to optimize the design. Testing is comprehensive using a production vehicle traction system as a baseline.

**Reviewer 3**

This reviewer believed that the team may want to consider a waterfall type chart to collect the accomplishments and highlight the manner that you targets are achieved.

**Reviewer 4**

This reviewer noted that baseline data (Chevy Bolt) and proposed data for a rare-earth mineral-free electric motor are outlined in the project report. Concept and tradeoffs study will be carried out and optimized design of the rare-earth mineral-free electric motor will be down-selected. Budget period 1 tasks are dedicated for

concept development, BP2 tasks are for design and optimization and sub-component and component testing and BP3 tasks are for system integration and system level verification of the rare-earth mineral-free electric motor. This approach is quite logical and systematic. Niron's expertise is being used for manufacturing of an iron-nitride permanent magnet. Inverter development will be carried out using 900V discrete MOSFETs populate down heavy-pour cooper printed circuit board (PCB), mostly using surface mount components including current sensors. Also, the project aims to reduce rare-earth-free magnets to maximum extent. Overall, this reviewer rated the project approach as excellent.

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

**Reviewer 1**

This reviewer believed that this is a well thought out project.

**Reviewer 2**

This reviewer said that the discussion and written presentation were both good.

**Reviewer 3**

This reviewer pointed out that preliminary optimization results for the rare-earth mineral-free motor are included in the project report. Layered magnets with V-shape are indicated in the project report. Limited amounts of coated nanoparticles of iron nitride magnets are produced. The possibility of uniform coating on iron nitride nanoparticles was verified. Tooling for magnet material manufacturing was designed and fabricated. The team measured and understood hysterias loops on deagglomerated nanoparticles dispersed and magnetically aligned in epoxy environment. Two concepts of traction inverter were illustrated in the project report and were described very well during the AMR presentation. Effects of parasitic inductance in the packaging of the gate driver with power stage were understood and layout with minimal inductance is illustrated in the project report.

This reviewer had a few concerns including SiC MOSFETs embedded in PCB, as PCB technology with high-voltage parts embedded may not be mature enough by completion of this project. Therefore, the project PI could have industry impacting contributions by focusing efforts on more feasible technology, which is to use discrete MOSFETs populated on a heavy-copper-pour PCB.

This reviewer has offered some suggestions. The discrete MOSFETs have a common footprint for 900V to 1200V blocking parts. Therefore, for technology with higher levels of confidence, 1200V SiC MOSFETs should be preferred over 900V SiC MOSFETs to achieve 300,000 miles reliability and 15 years life. Use of ceramic capacitors must be considered carefully, as capacitance value of these capacitors suffer from voltage and temperature related biases.

**Reviewer 4**

This reviewer perceived that the project is still in the planning stage

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

**Reviewer 1**

This reviewer found that this is a very experienced team with all the essential elements to be successful. Based on the progress, it is clear that collaboration is continuous.

**Reviewer 2**

This reviewer said that, though only 10% of the project is completed, universities (Marquette and Virginia Tech), supporting industries (Niron Magnetics and GM) and NREL are collaborating very well in execution of this project.

**Reviewer 3**

This reviewer found good planning between the collaborators

**Reviewer 4**

This reviewer suggested that the team may want to list the work or deliverables expected from each partner.

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

**Reviewer 1**

This reviewer found that there is a clear plan being executed.

**Reviewer 2**

This reviewer said that the future work is planned well and should help address many of the challenges.

**Reviewer 3**

The reviewer had no comments.

**Reviewer 4**

This reviewer said that the future work was described very well.

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

**Reviewer 1**

This reviewer believes that the project is critical to achieving a low cost, high power density application.

**Reviewer 2**

This reviewer found the project to be highly relevant to achieving the VTO electric powertrain goals.

**Reviewer 3**

This reviewer said that a rare-earth mineral-free electric machine will advance the DOE-VTO objective of strengthening the supply chain of electric motors and make these motors free from magnets imported from foreign soil, mainly China.

**Reviewer 4**

This reviewer said that this work supports achieving VTO traction drive targets.

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

**Reviewer 1**

This reviewer said that the project is on track.

**Reviewer 2**

The reviewer had no comments.

**Reviewer 3**

This reviewer said that the project team has all necessary resources and technical know-how and expertise.

**Reviewer 4**

This reviewer said that the team has the resources needed for a successful outcome.

**Presentation Number: elt264**
**Presentation Title: Demonstration of Utility Managed Smart Charging For Multiple Benefit Streams**
**Principal Investigator: Joe Picarelli, Exelon/Pepco Holdings Inc.**

***Presenter***

Stephanie Leach, Exelon/Pepco Holdings Inc.

***Reviewer Sample Size***

A total of four reviewers evaluated this project.

***Project Relevance and Resources***

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

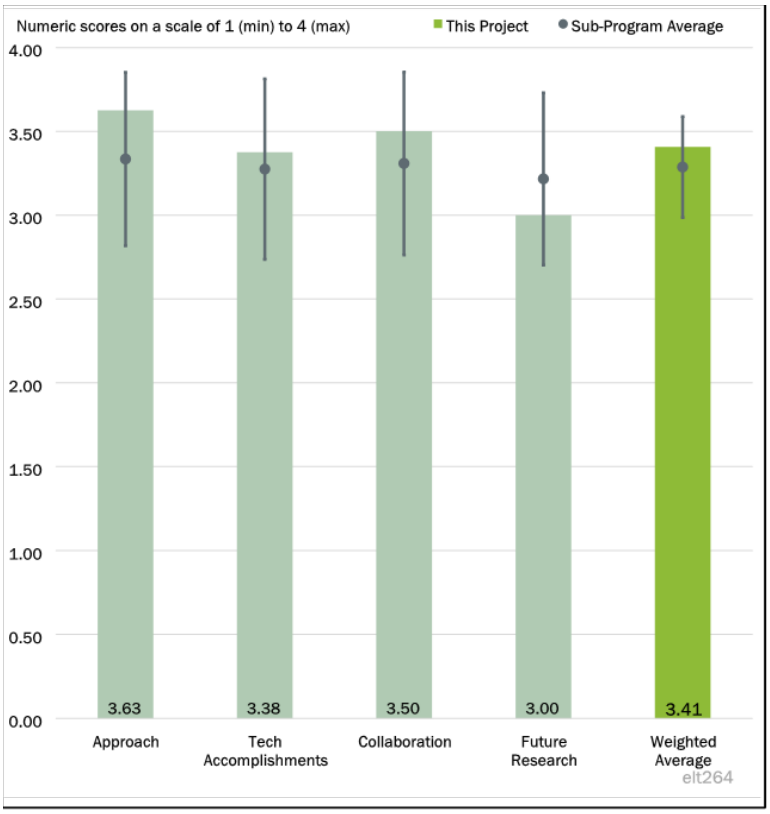


Figure 4-30 - Presentation Number: elt264 Presentation Title: Demonstration of Utility Managed Smart Charging For Multiple Benefit Streams Principal Investigator: Joe Picarelli, Exelon/Pepco Holdings Inc.

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

**Reviewer 1**

This reviewer said that the objectives and expected outcomes/milestones are clearly identified (Slide 6 of the presentation) and tie closely with the overall project objective of demonstrating large-scale smart charging.

**Reviewer 2**

This reviewer found that the approach was expertly planned and sought to answer the key questions related to EV charging. Including industry research and customer feedback is a huge advantage to project competitiveness among many others in the space. The principal investigator seems to have a good handle on such a massive project and is coordinating with many different aspects of the EV industry, which is important to gaining buy-in.

**Reviewer 3**

This reviewer defined the objectives of the project as: to research, develop, and conduct a wide-scale demonstration of a utility smart charge management (SCM) system; to develop optimal managed charging structures for grid value; to evaluate the impact of EV charging on local distribution utility operations; and to evaluate the utilities' ability to control EV charging load based on grid conditions. The reviewer identified as strengths the project appears to cover most major salient elements and demonstrates a logical progression from establishment of cybersecurity assessment/recommendations; identification of EVSE and telematics to receive

DR events; design of SCM demonstration; completion of ATEAM simulation software; development and conducting of a custom engagement program; and completion of model results to provide grid impact analysis.

He reviewer identified as weaknesses the project's go/no-go milestones could be stronger. No technical go/no-go milestones have been established and the third go/go-go milestone (December 2023) is the same as the December 2022 go/no-go milestone.

**Reviewer 4**

This reviewer felt that the project addresses the technical barriers and the project appears well designed and reasonably planned.

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

**Reviewer 1**

This reviewer said that the team is on track towards completing the project plan. Numerous milestones and objectives have been achieved successfully, including responses to prior year reviewers' comments. A key example is looking at cybersecurity vulnerability and defense strategies. It is also critical that the benefit and cost analysis be performed as planned (see Slide 9). Regarding this analysis, non-financial costs should be included as well, particularly regulatory barriers to implementation, i.e., what regulatory rules will need to be adopted to enable wide-scale smart charging. While the focus is the technical implementation and program demonstration, any regulatory barriers—such as lack of required rules for utility participation in smart charging—are as important as technical barriers in achieving successful smart charge deployment.

**Reviewer 2**

This reviewer said that the project appears to have made significant technical progress in the last year on all fronts with regards to cybersecurity, demand response using EVSE platforms, design of the customer SCM and launch of marketing recruitment planning, and the ATEAM grid simulation software tool.

Especially promising, according to the reviewer, is the cybersecurity progress, specifically the efforts to obtain broad feedback early on from stakeholders (including EVSE and telematics providers) on attack graphs, threat models, and identified vulnerabilities. Additionally, coordination with the National Institute of Standards and Technology best practices/guidelines and the MITRE ATT&CK framework is encouraging.

Furthermore, with regards to the customer SCM program, efforts here to specifically target and tailor smart charge measures to each customer segment is well received.

**Reviewer 3**

This reviewer found that many milestones have been achieved and the project is on track. The team did a great job on addressing cyber concerns and including customer feedback. The reviewer believes that these issues are front and center as managed charging and grid impacts are discussed.

**Reviewer 4**

This reviewer believed that the technical progress has been good except for the design for the SCM programs. The explanation for how the unique incentives were developed is lacking.

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

**Reviewer 1**

This reviewer affirmed that collaboration is key and found the project team to be collaborating well.

**Reviewer 2**

This reviewer said that the team is working well together and accomplishing complex tasks on both the technical and program side, including the integration with OpenADR and securing program approval from the Maryland Public Service Commission.

**Reviewer 3**

This reviewer said that the effort has a strong, balanced team that appears to fulfill all requirements to achieve the project objectives. This includes Baltimore Gas and Electric (BGE)/Pepco for project lead, integration, and customer demonstration program; Argonne National Laboratory for grid impact analysis/modelling, cost benefit analysis, and cyber assessment; Shell Recharge Solutions to serve as a hardware and network provider; WeaveGrid as a telematics software solution provider and for evaluation of the ability to control EV charging load; and the Smart Electric Power Alliance to provide SCM program market research. There do not appear to be any overt gaps within the project team, nor lack of availability of resources and equipment to appropriately conduct project activities.

**Reviewer 4**

This reviewer said that there is a good representation of different types of partners.

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

**Reviewer 1**

This reviewer said that the project has done a good job of comprehensively identifying remaining programmatic, business, and technical barriers. The budget period 4 proposed research is a logical progression from the previous year, and can be assumed to address the remaining barriers. Additional detail under each element of the expected outcomes/milestones of budget period 4 would have been beneficial to further clarify expectations.

**Reviewer 2**

This reviewer said that the team has noted two remaining barriers and challenges but its proposed future research does not include a plan to address them. The two barriers are, “Not all EVSE hardware providers can perform DR events for public program” and “Inconsistent firmware on EVSE used across fleet and public programs.” (Slide 11) The solution involves interoperability and standards; the team should identify which existing standards are available to solve the problems.

**Reviewer 3**

This reviewer felt that the project needs to clearly identify incentives and what is the appropriate level to get customers to participate. This is important especially to get participation in SCM at scale.

**Reviewer 4**

This reviewer saw the reliability of EVSE equipment and how downtime may affect managed EV charging pilots as a challenge forthcoming. The reviewer suggested that, with firmware being inconsistent and physical hardware being possibly unreliable, one way to work around this would be a service level agreement that seeks a standard amount of uptime and coordinates across all vendors (Shell Recharge, Weave Grid, etc.).

Another issue could be a possible large T and/or D impact is found. The reviewer questioned how that would impact BGE operations at scale, especially in power delivery, workforce planning, Etc. The reviewer believed that downstream impacts do not have to be solved for in this project but they should be identified to spark industry discussion.

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

**Reviewer 1**

This reviewer said that the project aligns with subprogram objectives.

**Reviewer 2**

This reviewer pointed out that the project targets VTO's Smart Charge Management objectives. Specifically, it tests a potentially (depending on the cost-benefit analysis and consumer adoption) viable smart charge management strategy, as well as specific tools (e.g., ATEAM) relevant to creating, implementing, and operating smart charge management programs at scale. The reviewer raised the question as to what interoperability standards are needed to scale such programs and achieve the best economics.

**Reviewer 3**

This reviewer found that this project is highly relevant. If successful, the project will facilitate earlier, more widespread and resilient EV-grid integration, which will enable EVs at scale. Specifically, this will be achieved through reduced EV charging impacts on utility distribution/transmission systems, lowering of capital investment requirements, and early identification of cybersecurity risks and vulnerabilities.

**Reviewer 4**

This reviewer found that the program supports electrification.

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

**Reviewer 1**

This reviewer said that the resources are sufficient and the project should meet the milestones on time.

**Reviewer 2**

This reviewer said that, based on experience with comparable pilot programs such as California's Statewide Pricing Pilot and more recent Residential TOU Program Pilot, the budget appears adequate.

**Reviewer 3**

This reviewer said that the resources identified are sufficient for the identified scope and duration of this project.

**Reviewer 4**

This reviewer said that the project has sufficient resources.

**Presentation Number: elt265**
**Presentation Title: A Secure and Resilient Interoperable Smart Charging Management (SCM) Control System Architecture for Electric Vehicle's-At-Scale**
**Principal Investigator: Duncan Woodbury, Dream Team LLC**

***Presenter***

Duncan Woodbury, Dream Team LLC

***Reviewer Sample Size***

A total of three reviewers evaluated this project.

***Project Relevance and Resources***

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

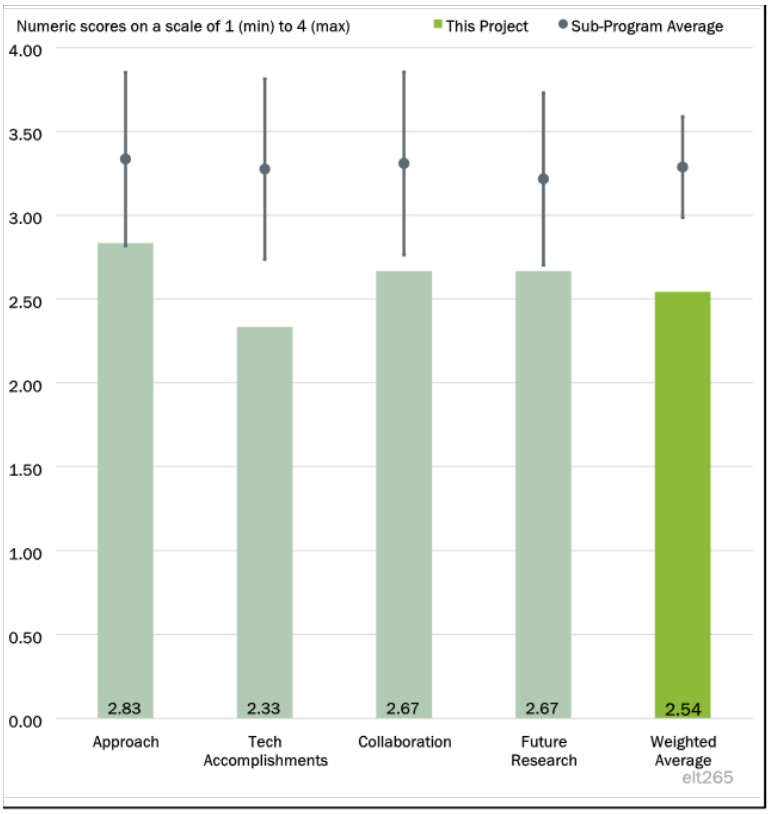


Figure 4-31 - Presentation Number: elt265 Presentation Title: A Secure and Resilient Interoperable Smart Charging Management (SCM) Control System Architecture for Electric Vehicle's-At-Scale Principal Investigator: Duncan Woodbury, Dream Team LLC

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

**Reviewer 1**

This reviewer said that the approach seems generally aligned with addressing the identified technical challenges related to interoperability and cyber security concerns from heterogeneous electrified vehicles, charging stations, and distributed energy resources connecting with each other and the utility grid.

**Reviewer 2**

This reviewer said that the approach seems good. The project relevance could be described in a more effective graphical format.

**Reviewer 3**

This reviewer said that the approach appears to focus on both security and interoperability but does not list existing standards for a comparison with this project's objectives of creating a new standard. According to the reviewer, IEC61850-90-8 is being used but this is obsolete and IEC 61850-7-420 should be used instead.

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

**Reviewer 1**

This reviewer found the presentation difficult to follow and, thus, the impact of the accomplishment was unclear.

**Reviewer 2**

This reviewer said that the presentation reported accomplishments related to system architecture development (though it needed to clarify completion dates for this in 2021 rather than 2022), data model specification, and laboratory testing/demonstration. It would, however, be beneficial for the project to more closely follow best practices to define "SMART" milestones—particularly the specific and measurable elements of the mnemonic, along with being achievable, relevant and time bound.

**Reviewer 3**

This reviewer said that significant variations to interoperability vary with architectural differences for direct current fast-charging ( DCFC) versus DWPT. This is not addressed. The focus seems to be on multiple power levels of DCFC where that is not a factor for security or interoperability.

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

**Reviewer 1**

Tis reviewer said that the project includes a good diverse team of listed contributors, spanning utility stakeholders and national laboratory and university collaborators, along with industry partners and multiple test and demonstration locations.

**Reviewer 2**

This reviewer said that the partners are diverse but more needs to be identified regarding their resources to provide results for the tasks.

**Reviewer 3**

This reviewer said that the collaborative aspects of the project were not clear.

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

**Reviewer 1**

This reviewer found that the described future work seems on track and appropriate—noting that the listed activities will span the upcoming budget period through the remainder of FY22 and FY23, but that there will be further activities happening in the final portion of the project through the end of 2024.The reviewer believed, however, that it would be good to strengthen the specificity and quantifiable metrics associated with the future milestones wherever possible.

**Reviewer 2**

This reviewer said that the proposed work seems consistent with the plan, but the broad goals of the project are still somewhat obscure.

**Reviewer 3**

This reviewer suggested that clarity needs to be included as to the approach for vehicle grid integration versus V2G. Is the approach to only control the EVSE or insure security and interoperability to the EV?

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

**Reviewer 1**

This reviewer felt that a stronger, more concise, and graphical explanation of the targets and accomplishments would significantly enhance communication of the relevance of this project.

**Reviewer 2**

This reviewer said that the project is relevant to the electric vehicle, grid, and charging infrastructure interoperability and cyber security considerations of concern to the VTO Electrification Program.

**Reviewer 3**

This reviewer affirmed that this an important project as electrification increases and the grid also changes to include more clean energy options. Matching these needs will continue to be a challenge as these changes are evaluated.

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

**Reviewer 1**

This reviewer said that the resources seem sufficient.

**Reviewer 2**

This reviewer said that the resources appear to be adequate for the project, with DOE providing a little over 2/3 of the funding, and cost share from the project team covering the remainder.

**Reviewer 3**

This reviewer believed that assignments need to be identified to point out the strengths of them and how they will best fit in obtaining expected results. Each stakeholder support and expected contribution needs to be identified to provide positive results to the project.

**Presentation Number: elt266**
**Presentation Title: Next Generation Profiles: High Power Charging Characterization**
**Principal Investigator: Dan Dobrzynski, Argonne National Laboratory**

### *Presenter*

Dan Dobrzynski, ANL

### *Reviewer Sample Size*

A total of five reviewers evaluated this project.

### *Project Relevance and Resources*

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

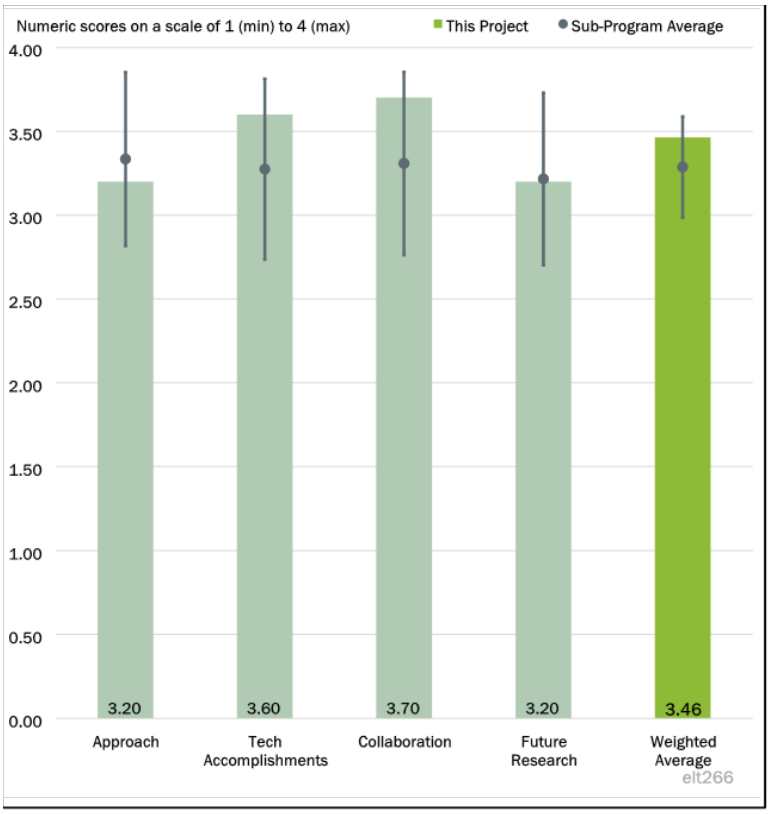


Figure 4-32 - Presentation Number: elt266 Presentation Title: Next Generation Profiles: High Power Charging Characterization Principal Investigator: Dan Dobrzynski, Argonne National Laboratory

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

**Reviewer 1**

This reviewer said that the Involvement of partners, standards groups, and the Grid Integration Technical Team in the development of procedures helps assure that the data collected will be useful for planning grid and charge infrastructure development.

**Reviewer 2**

This reviewer found that the team has a comprehensive plan for obtaining data. One concern the reviewer raised is the ability to correlate lab testing with actual field conditions, noting that field data is noisy and difficult to obtain, but lab data may or may not reflect actual usage patterns. The plan does have some accommodation of those concerns, though.

**Reviewer 3**

This reviewer believed that there is an implied assumption that the measured HPC profiles are relatively static and will not change with time. It appears that most vehicle OEMs limit the number of times that fast charging can be used (to prevent battery life degradation). It is also possible that as more fast charging cycles are completed, the charging profile may be changed to ensure longer battery life. Also, as more vehicles start offering HPC, and the take rate goes up, the impact on the grid will become clearer, and may lead to further modification of the HPC profiles.

The reviewer also questioned whether XFC and HPC defined in terms of power level or C-rate. Defining it in terms of power level makes sense because the primary goal is to study the grid impact, and not the impact on the battery (though the reviewer felt that, as long as the money is being spent, it makes sense to study the impact on the battery as well). However, as one of the reviewers pointed out in the previous year, the definitions as used by the PI may be confusing, since apparently XFC is generally defined in terms of C-rate.

**Reviewer 4**

This reviewer said that achieving this project's objectives regarding identification and characterization of HPC profiles requires broad participation by providers of EVs and EVSEs, a difficult task that has been largely successfully achieved. The EVSE characterization utilizes an EV emulator load; it is unlikely that the emulator will reflect the diversity of charging behavior of actual EVs of different types and models. It would be more valuable to characterize EVSE's by using actual EV loads, even though this is more difficult. Regarding the timeline, the Year 2 Milestones do not appear likely to be achieved on schedule, though it is possible that the delays will not affect overall project completion.

**Reviewer 5**

This reviewer believed that the approach to the work is very good. This is creating a set of power profiles for potential future grid evaluations. The reviewer did, however, have some concerns about how the creation of these data will align with a full fleet of vehicles, the wide spread of potential vehicle use cases, and potential future smart charging or pre-charging preparations where drivers know they are going to charge and the vehicle preps the battery for charging prior to reaching the charge station.

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

**Reviewer 1**

This reviewer thought that the team has done an excellent job of getting engagement from OEMs and fleet managers, particularly considering pandemic-related restrictions. It appears to be well-positioned for the next phase of the project.

**Reviewer 2**

According to this reviewer, the data acquisition systems look good. The reviewer expressed hope to see a distribution of charging profiles that estimate not only a current nominal, but also a future nominal that includes forecasting improvements in hardware, system integration, and controls.

**Reviewer 3**

This reviewer said that, despite the COVID-19 related delays, significant progress has been made on the project.

**Reviewer 4**

This reviewer found that, overall, achieving the technical goals has been very successful, including the enrollment of partners, EVSE characterization, and fleet data collection. The Year 2 Milestones do not appear likely to be achieved on schedule, though it's possible the delays will not affect overall project completion.

**Reviewer 5**

This reviewer said that a significant amount of data has been collected in spite of some setbacks in asset availability and interest in the field. Development of post-collection analysis remains to be accomplished. This task is critical to bringing value to the data collected.

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

**Reviewer 1**

This reviewer found that the procedure reviews within the labs and coordination of data collection with vehicle manufacturers, EVSE suppliers, fleet operators and electric utilities was excellent.

**Reviewer 2**

This reviewer said that each team member has clearly-defined roles and appears to be interacting appropriately.

**Reviewer 3**

This reviewer said that the four lab partners have shown previous success working together on similar projects. The reviewer was hopeful that continued OEM involvement will continue to make the results valuable to all future users.

**Reviewer 4**

This reviewer found that the PI has done due diligence and reached out to various vehicle and EVSE OEMs and labs, though some partners appear to have pulled back.

**Reviewer 5**

This reviewer believed that, while the current team is working well together, the team does not include any EVSP participants. EVSPs, which lead the design and construction of charging depots, will be among the main customers of the outputs of this research. EVSPs will use this research to plan their depots, engineer their utility interconnections, and participate in grid service offerings. The data will be the main input to determining how to manage loads to minimize electricity costs for HPC sites, because demand charges are the largest determinant of those costs. Accordingly, addition of one or more leading EVSPs to the team as an advisor or participant is highly recommended.

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

**Reviewer 1**

This reviewer said that the team has a good plan and is well-positioned for the next phase. However, this is a highly fluid technology space, with new vehicles and EVSE being released regularly. Flexibility is required to ensure broad impact, but the team is struggling some to turn letters of intent into contracts. This is a relatively minor concern, related not to the quality of the work but to its breadth.

**Reviewer 2**

This reviewer suggested that collaborative engagements should include one or more leading EVSPs as described in the response to Question 6. EVSE characterization should go beyond the emulator and include actual vehicles.

**Reviewer 3**

This reviewer noted that, as the PI has mentioned, there needs to more effort to engage other OEMs and partners.

**Reviewer 4**

This reviewer pointed out that the project mentions SAE, Electric Power Research Institute (EPRI), Energy Star for Utilities that participate. The reviewer would like to see more information from the electric utilities on how the data are valuable to them for grid forecasting and minimizing disruptions or for optimizing the current system to provide a robust charging experience to future EV users.

**Reviewer 5**

This reviewer said that analysis, results, and reporting is only one of four milestones for Year 3. This work is what brings value to all the effort to collect data. It should receive a much higher priority for future research.

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

**Reviewer 1**

This reviewer said that the project is relevant to both ELT and Energy Efficient Mobility Systems.

**Reviewer 2**

This reviewer said that the project provides data that are central to future grid studies.

**Reviewer 3**

This reviewer found that the project matches the following goal: "HPC: Develop strategies and technologies for high power dynamic wireless charging and multi-port 1+ MW charging stations that enable vehicle charging through direct connection to medium voltage (≥ 12.47 kV) distribution." While the goal specifies 1+ MW charging, there are no vehicles available that can accept such charging levels. It has been reported (Electrek, October 12, 2021) that Tesla has deployed a 1 MW charger; the project should attempt to obtain/borrow a MW charger from Tesla or other source and include it in its EVSE characterization efforts.

**Reviewer 4**

This reviewer said that, while benchmarking/measuring currently available products isn't directly changing the future electrification needs, the data will be useable for forecasting and proposing changes to improve the overall EV adoption rate.

**Reviewer 5**

This reviewer said that the project provides a baseline of data that will gain relevance only once it is analyzed for specific use cases.

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

**Reviewer 1**

This reviewer noted that the project reaches out to many groups to collect data. While there have been some setbacks in gaining cooperation with the project, the reviewer believes that this does not appear to be from lack of resources trying. The amount and variety of data collected is impressive.

**Reviewer 2**

This reviewer expressed to having no concerns about the resource level. The team is doing well to trade data for equipment access.

**Reviewer 3**

This reviewer said that the presenter noted that, in line with previous reviewer comments, the project resources are sufficient.

**Reviewer 4**

This reviewer found that the list of participating labs, vehicles, and equipment appear sufficient to achieve the project goals listed to be complete in Oct 2023.

**Reviewer 5**

This reviewer opined that the resources are sufficient as of now, but if there are a large number of HPC capable vehicle models available for sale in the near future, the budget may need to be increased so that a good data set can be generated.

**Presentation Number: elt274**
**Presentation Title: eMosaic: Electrification Mosaic Platform for Grid-Informed Smart Charging Management**
**Principal Investigator: Alex Brissette, ABB**

***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.

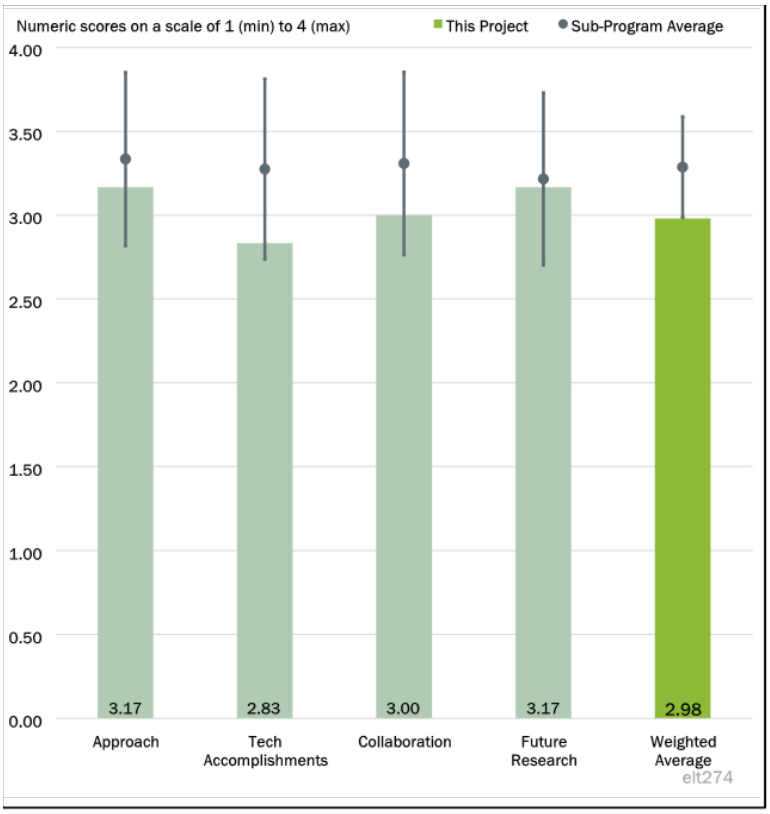


Figure 4-33 - Presentation Number: elt274 Presentation Title: eMosaic: Electrification Mosaic Platform for Grid-Informed Smart Charging Management Principal Investigator: Alex Brissette, ABB

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

**Reviewer 1**

This reviewer believes that the project appears to be well designed to address technical barriers and that the timeline is reasonable.

**Reviewer 2**

This reviewer said that the project's approach is well designed. The timelines have slipped a bit but that is expected given the ongoing pandemic and supply chain struggles.

**Reviewer 3**

This reviewer wanted to see the details on how the platform architecture on Slide 10 was selected including whether other architectures were considered, and if so how were they evaluated.

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

**Reviewer 1**

This reviewer found that the project seems generally on track.

**Reviewer 2**

This reviewer said that technical progress is well documented But information on how cybersecurity is being addressed is lacking wand will be important for integration with multiple platforms (utility, charging network operator, facility, and fleet management).

**Reviewer 3**

The reviewer had concerns that while the project may end up showing technically feasible results, the findings won't translate to implementation at scale.

The reviewer said that any project approach should consider the minimum NEVI standards being proposed by the joint DOE/U.S. Department of Transportation office. Plug and Charge (ISO 15118) is being considered as mandatory and there could be other developments such as cybersecurity modifications, after the comment period ends.

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

**Reviewer 1**

This reviewer found that the partners are well coordinated in tasks and contributions. The reviewer suggested that opportunities for stronger collaboration with fleet operators will occur moving forward and will be helpful with input to the project.

**Reviewer 2**

This reviewer thought that the project could be a candidate to be included in the EVs@ Scale Consortium as that project takes shape. Either way, the reviewer recommended more utility involvement, through EPRI or others. Good to see the ASPIRE Center is involved.

**Reviewer 3**

This reviewer would have liked to see specifics in the accomplishments section regarding which collaborators are responsible for the various outcomes that were reported out.

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

**Reviewer 1**

This reviewer said that the proposed future work is in line with the project plan.

**Reviewer 2**

This reviewer said that the proposed work will achieve targets and address barriers.

**Reviewer 3**

This reviewer believed that the proposed future research has implications for the entire industry and will be valuable to all involved. The project plan acknowledges future research challenges and the need for additional stakeholder engagement, including the addition of a charge point operator. The reviewer believed that to be important because, according to the reviewer, if this project were developed without a network charge point operator involved, it would face much more scrutiny and acceptance challenges to commercialization.

Additionally, the ability for multiple utilities to follow project developments would be beneficial, especially if there are opportunities for pilots in other parts of the country.

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

**Reviewer 1**

This reviewer said that the project is relevant to grid-scale adoption of smart charging.

**Reviewer 2**

This reviewer said that the project supports the VTO program objectives.

**Reviewer 3**

This reviewer said that the project supports electrification and analysis.

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

**Reviewer 1**

The resources seem sufficient.

**Reviewer 2**

Resources appear to be sufficient.

**Reviewer 3**

This reviewer said that the project is relatively on schedule given the industry-wide challenges. No additional resources specific to the project is needed but additional stakeholder input is recommended.

**Presentation Number: elt277**
**Presentation Title: Electric Vehicle Integrated Safety, Intelligence, OperatioNs (eVision)**
**Principal Investigator: Madhu Chinthavali, Oak Ridge National Laboratory**

***Presenter***

Madhu Chinthavali, ORNL

***Reviewer Sample Size***

A total of three reviewers evaluated this project.

***Project Relevance and Resources***

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

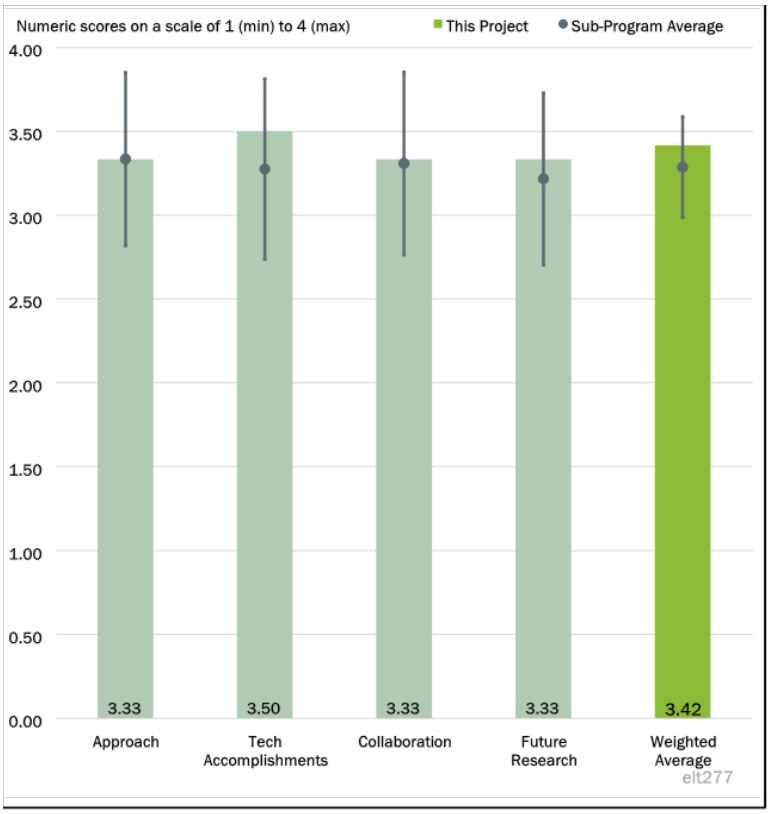


Figure 4-34 - Presentation Number: elt277 Presentation Title: Electric Vehicle Integrated Safety, Intelligence, OperatioNs (eVision) Principal Investigator: Madhu Chinthavali, Oak Ridge National Laboratory

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

**Reviewer 1**

This reviewer said that the technical barriers are addressed, the project is well designed, and the timeline is reasonable.

**Reviewer 2**

This reviewer believed that maintaining charging with minimal human interaction to recover from charge faults will help with the vehicle utility and overall adoption. Regarding the charging bank system designs, the reviewer asked whether there will be an optimization of the size of the ESS regulating the PCC and microgrid voltages. This component appears to have a large expense in the overall system, according to the reviewer so that using the throttling controls to minimize that ESS size will help reduce cost and improve adoption.

**Reviewer 3**

This reviewer said that the approach for the project is extremely complex and includes nine subtask areas. According to the reviewer this makes it somewhat difficult to follow, though, the reviewer recognizes that the project is trying to address multiple complex issues. Overall, the reviewer believes that it is really important that the project is looking to address charger outages, which has become a bit of an issue for the market. The

project is focused specifically on three primary charger outage causes. This is an area where utility perspective may have been useful, according to the reviewer..

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

**Reviewer 1**

This reviewer said that the project made a good evaluation of charger architecture, controls and grid faults. The integration work was well done.

**Reviewer 2**

This reviewer said that ORNL has been able to characterize in detail several fault cases as well as related operating strategies for the use cases, for chargers both with and without storage. Idaho National Laboratory has been emulating failure modes in the lab to figure out how to set up hardware operation to address the various cases. Meanwhile, Pacific Northwest National Laboratory has worked to evaluate system control responses and focused on Charging Architecture Development Station Optimization and Control. Overall, the team has investigated a large number of use cases and responses in detail. While the complexity of the project approach/design makes it a bit tough to have a clear feel for the overall technical accomplishments and how they fit together, the team does appear to have accomplished a great deal. The real test will be to see how the team ties it all together.

**Reviewer 3**

This reviewer said that maintaining charging with minimal human interaction to recover from charge faults will help with the vehicle utility and overall adoption. The testing of the system and demonstrating the throttling of charge rate fast enough to prevent trips is good proof that the system is functioning as intended.

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

**Reviewer 1**

This reviewer found that the five partners have produced good data so far. Nothing in the material indicates any of the partners are falling short.

**Reviewer 2**

This reviewer said that, overall, the project has a good team between national labs and ABB. Since grid faults are a major component, the project team should get feedback from a utility.

**Reviewer 3**

This reviewer noted that the project includes three labs, a charger manufacturer, and a university, suggesting that it would have been good to include a utility to provide an additional perspective related to the grid. The team has worked hard to ensure that the labs are collaborating on tasks. The same team is also leveraging three other DOE VTO projects.

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

**Reviewer 1**

The project team identified several specific future challenges and barriers to address, based upon what they have accomplished to date and what they still want to achieve. They have laid out the remaining activities for FY2022 and FY2023.

**Reviewer 2**

This reviewer said that the project should explore testing beyond hardware in the loop and include field tests.

**Reviewer 3**

This reviewer said that the project does demonstrate many use cases. The future proposed research lists "Creating more use cases for the anomaly detection using test data from the chargers" but does not specify what methods or feedback from utilities and charger OEMs will be used to demonstrate that the droop and fault detection is comprehensive and not specific.

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

**Reviewer 1**

This reviewer said that the project aligns with electrification objectives.

**Reviewer 2**

This reviewer said that the project is focused on charging station resiliency (including impacts on the grid and cyber security), charger approaches for MD/HD EVs, and charging station architecture for extreme fast chargers and that these are all of great relevance to the DOE program.

**Reviewer 3**

This reviewer said that EV charging robustness to many use cases and potential systems faults will improve vehicle utility and the adoption rate of technology.

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

**Reviewer 1**

This reviewer said that the project resources are sufficient and it is expected that the milestones will be met in a timely fashion.

**Reviewer 2**

This reviewer said that there was no indication of concerns on resources.

**Reviewer 3**

This reviewer said that the material does not list a resource shortfall to completing in 2023. The partners appear to be on track.

**Presentation Number: elt278**
**Presentation Title: Electric Vehicles (EVs) at Scale Laboratory Consortium**
**Principal Investigator: Andrew Meintz, National Renewable Energy Laboratory**

***Presenter***

Andrew Meintz, NREL

***Reviewer Sample Size***

A total of five reviewers evaluated this project.

***Project Relevance and Resources***

80% of reviewers felt that the project was relevant to current DOE objectives, 20% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 40% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 40% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

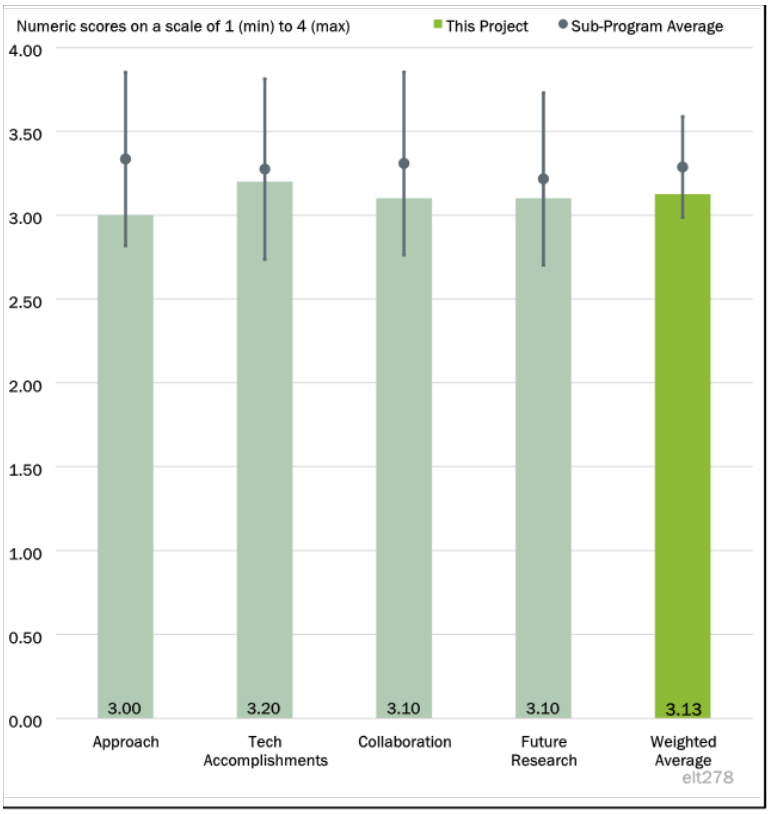


Figure 4-35 - Presentation Number: elt278 Presentation Title: Electric Vehicles (EVs) at Scale Laboratory Consortium Principal Investigator: Andrew Meintz, National Renewable Energy Laboratory

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

**Reviewer 1**

This reviewer said that the approach is very methodical and of long duration. High Power automatic charging should not be ignored. It will be a major part of the future. Drayage, trucks, and buses with large depots need to have high power automatic charging.

**Reviewer 2**

This reviewer said that the project tackles the disparate threads that make up the charging infrastructure and what is required to make widespread EV adoption feasible. But, the dynamic roadway charging thread seems very speculative compared to the others.

**Reviewer 3**

Four of the five project areas address significant barriers to EV charging deployment; the fifth, dynamic wireless charging (wireless power transfer [WPT]), is a high-cost solution to address what may or may not be a problem (battery weight). As this project proceeds, the WPT project should address additional implementation barriers to the dynamic wireless approach, specifically standardization of vehicle assemblies to allow for scaling, including having the same standard for static wireless charging, and the metering and billing component—consumption is now measured as part of the data collection, but there also has to be consideration of authentication (what happens if a non-registered vehicle consumes power from the road), how is the metered

load being served from the utility reconciled with the total consumption of the vehicles that receive power from that section of the road, and so on. The Codes and Standards activity should be expanded to include open charge point protocol (OCPP), a critical interface between chargers and back-end clouds that is used by the vast majority of charger manufacturers to enable remote monitoring and control, including authentication and payment processing. This standard is required by some states and programs, as well as implied in the NEVI notice of proposed rulemaking, but its further development and improvement would benefit from DOE support, including becoming an ISO standard (it is currently managed by the Open Charge Alliance, which is not a recognized SDO).

**Reviewer 4**

The timeline makes sense. However, with a new project and any multi-stakeholder process, progress could be expected to slow down.

The reviewer asked a number of questions believing them to be very relevant to the utility space: whether DOE is communicating broadly with utilities that these efforts are underway; whether a dialogue with EPRI would or EEI or both be useful. It seems there are limited opportunities for utilities to engage (one or two utilities per project) but the challenges are industry-wide. Broader communication could be useful in bringing the industry along at speed.

**Reviewer 5**

This reviewer pointed out that the project is divided into five pillars: vehicle grid integration and smart charging management, high power charging, wireless power transfer, cyber-physical security, and codes and standards. Each of the five pillars has its set of deliverables and due dates. The deliverables and due dates seem satisfactory.

However, the overall weakness of this project is that there does not seem to be a coherence among the five pillars in terms of how they support each or how they relate to each to make a whole. It is as if the five pillars are five separate disparate, distinct tasks with separate, disparate and distinct goals/objectives but with no interdependency with each other (except that they relate to electric vehicles) and thrown thoughtlessly together. Therefore, this reviewer would not say that this is a well-designed project.

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

**Reviewer 1**

This reviewer noted that the project is new and just getting rolling, and believed that it has made good progress so far.

**Reviewer 2**

This reviewer found that the projects are generally on schedule in spite of COVID-19 delays. The project teams have identified and overcome technical barriers successfully and have engaged stakeholders effectively.

**Reviewer 3**

This reviewer pointed out that it is a long duration program that is just beginning and believed that significant accomplishments have been made for the plan.

**Reviewer 4**

This reviewer believed that Flexible charging to Unify the grid and transportation Sectors for EVs at Scales' (FUSE) "Grid Impact" needs to be further defined, including whether it is T or D or both and, how customer behavior impacts findings. The reviewer questions whether, if FUSE makes technologically feasible recommendations for smart charge management, those recommendations will be acceptable to consumers and businesses. The end in mind is, according to the reviewer, that society should not be made to feel that they are giving up convenience to drive electric.

For WPT, the reviewer points out that The Ray, a nonprofit in La Grange, Georgia, has already been heavily involved in the space. Allie Kelly is their CEO and the reviewer believes that it would be worth a discussion with her prior to developing a complete project plan.

For the cybersecurity pillar unified national lab collaboration, Plug and Charge is very important as this standard is being proposed in the NEVI program guidance released June 10th. If possible, ISO 15118 lab testing may need to be accelerated due to NEVI implementation should this path be endorsed by the joint office.

**Reviewer 5**

This five-year project is only six months in progress, so no technical accomplishments have been made.

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

**Reviewer 1**

This reviewer said that the project is new but appears well organized amongst the national lab participants but believed that reviewers are somewhat handicapped by not knowing the exact composition of the external advisory council, which seems key to judging the quality of the collaboration.

**Reviewer 2**

This reviewer noted that the effort requires substantial collaboration and coordination across the labs and with stakeholders in academia, government and industry. The leadership is managing this effectively and achieving broad engagement and stakeholder input. One example is the sharing of data across different models to leverage the benefits of the various modeling efforts (e.g., BEAM). Another example from personal experience is the MCS open standard activity, where literally hundreds of stakeholders have participated in information exchanges and in providing input to the standards development.

**Reviewer 3**

This reviewer said that, in general, the correct partners have been assessed and are being assigned. It is very important to keep the utilities engaged, including EPRI.

**Reviewer 4**

This reviewer found that deep collaboration is required for a project of this scope and has already been included in the project plan.

**Reviewer 5**

This reviewer found that the collaboration and coordination are extremely limited because the only partners are all national laboratories. There are no manufacturers, suppliers or user organizations involved. Even the Federal Highway Administration (FHWA), which is involved with regulating roadways and researching roadway construction techniques, is sorely left out as a partner The reviewer questioned, for example, why this project is evaluating representative asphalt materials when the FHWA Turner-Fairbanks Highway Research Center in McLean, VA is the Federal center of excellence in this very area and why should the national laboratories be duplicating the work of another Federal agency. The reviewer also believed that suppliers and manufacturers of wireless power transfer equipment already in use at two locations, e.g., Antelope Valley Transit Agency and Foothill Transit, have been left out of the picture.

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

**Reviewer 1**

This reviewer found that the proposed future research is excellent. However, these are systemic industry challenges so defined research vs. outcomes will be important to address in future AMR reviews.

**Reviewer 2**

This reviewer said that the next steps appear promising and touch on the key elements of making EV charging widely available and effective.

**Reviewer 3**

This reviewer said that the program is just beginning and the team has laid out an excellent future plan but that the program needs to include automated charging for trucks because automated charging in a depot setting is needed and robotics for MCS is not a solution. Power needs with 1400 vehicles for a fleet will be cumbersome without automation.

**Reviewer 4**

This reviewer suggested that the WPT project would be much more valuable if it addressed commercial as well as technical implementation issues, such as how EV drivers would be billed for charging consumption, how utilities would be reimbursed, who might realistically own the infrastructure and how would they recover their invested capital, etc. The project would benefit from added engagement with EV charging station operators and utilities. The Codes and Standards research should support OCPP. development and evolution, because industry has largely standardized on this protocol already, and its further development is critical to enhancing the efficiency and reliability of EV charging, especially at public stations. While its support for 15118 is a good start, the Codes and Standards research should also consider supporting development of strategies for the transition from 15118-2 to 15118-20, which poses some challenges for the EVSE manufacturers.

**Reviewer 5**

This reviewer said that the future research in the High-Power Charging pillar of this project seems to have a clear purpose but this reviewer questions the need for this particular pillar of the project. The principal investigator needs to explain why an on-site distribution system should accommodate 1+MW scale charging, LD, MD, HD Long Dwell, LD Short Dwell;, 100kW, and 300kW charging all at the same time. The reviewer asked if the application is targeted for a diversified user such as a rental truck location?

The future research in the Dynamic Wireless Power Transfer in Roadways pillar of this project seems to have a clear purpose but this reviewer questions the need for this particular pillar of the project. The Dynamic Wireless Power Transfer in Roadways pillar of this project appears to duplicate ELT 239, "High Power Inductive Charging System Development and Integration for Mobility," ELT 240, "Wireless Extreme Fast Charging for Electric Trucks," and ELT 197, "High Power and Dynamic Wireless Charging of Electric Vehicles." The reviewer suggested that the principal investigator of this project needs to distinguish this project from the other three ELT projects just mentioned and justify the rationale for duplicate work effort.

The future research for cyber-physical security seems to be targeted for high power electric vehicle charging. However, it is not even clear that high power electric vehicle charging is sufficiently robust and justified to launch widespread use of this technology.

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

**Reviewer 1**

This reviewer said that the project supports the VTO electrification initiative to accelerate EV adoption by tackling key issues with charging infrastructure.

**Reviewer 2**

This reviewer said that there are strong synergies between many of the individual projects within the VTO subprogram and the elements of this project, particularly in the high level system and grid modeling and analysis. This project takes an ecosystem approach that reflects the structure of the EV and EV charging ecosystems to deliver more impactful results overall.

**Reviewer 3**

This reviewer found that the program is very relevant for the future.

**Reviewer 4**

This reviewer said that the project supports Electrification specifically.

**Reviewer 5**

This reviewer said that, although this project touches on the analysis and electrification subprograms of the DOE VTO, this reviewer does not see immediate, widespread needs for high power electric vehicle charging and dynamic wireless power transfer in roadways except in infrequent, specialized niche applications.

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

**Reviewer 1**

This reviewer said that the resources appear adequate.

**Reviewer 2**

This reviewer noted that this a large and complex project but has substantial resources dedicated to it, finding that the approaches, accomplishments (for historical context), near-term tasks, and deliverables are consistent with the overall budget.

**Reviewer 3**

This reviewer said that the resources are sufficient for the program, but the program is not required, in general.

**Reviewer 4**

This reviewer said that this is a new project with heavy coordination aspects. Coordination across industry, labs, etc. will only increase as the project stands up workstreams. Unless there is a strong support system already identified now, the reviewer expected that more resources will be required in the near future. Additionally, more resources could be used to communicate on behalf of the project specifically. Or, DOE VTO could contract with other industry partners to bring in additional stakeholders as part of the communication process. The reviewer recommended that the project team think through a communication and stakeholder engagement plan—both with the planned project team, and with industry in general.

**Reviewer 5**

This reviewer said that $65 million is an excessively high amount for this project. Because a lot of previous effort has taken place, one would expect that taking advantage of that previous effort would bring the total cost down. Unfortunately, the breakdown of resources is invisible, and this reviewer would like to see a breakdown of how those resources will be spent among the five pillars.

## Acronyms and Abbreviations

| | |
|---|---|
| °C | Degrees Celsius |
| ACM | American Center for Mobility |
| AMR | Annual Merit Review |
| BG&E | Baltimore Gas & Electric |
| BGE | Baltimore Gas and Electric |
| C | Charge rate |
| CNG | Compressed natural gas |
| COVID-19 | Coronavirus disease 2019 |
| Cu | Copper |
| DC | Direct current |
| DC | Direct-current fast-charging |
| DWPT | Dynamic wireless power transfer |
| EDT | Electric Drive Technology(ies) |
| EDU | Electric drive unit |
| EERE | Office of Energy Efficiency and Renewable Energy |
| ELT | Electrification program |
| EM | Electromagnetic |
| EPRI | Electric Power Research Institute |
| EV | Electric vehicle |
| EVs@Scale | Electric Vehicles at Scale Consortium |
| EVSE | Electric vehicle supply equipment |
| EVSP | Electric vehicle service provider |
| FEA | Finite element analysis |
| FUSE | Flexible charging to Unify the grid and transportation Sectors for EVs at scale |
| FY | Fiscal Year |
| GaN | Gallium nitride |
| GaN | Gallium nitride |
| GHG | Greenhouse gas |
| GM | General Motors |
| HD | Heavy-duty |
| HELICS | Hierarchical Engine for Large-scale Infrastructure Co-Simulation |

| | |
|---|---|
| HPC | High-power charging |
| HRE | Heavy rare earth |
| IIC | Indiana Integrated Circuits |
| IIT | Illinois Institute of Technology |
| IMSwTPG | Insulated metal substrate with thermally annealed pyrolytic graphite |
| IPM | Interior permanent magnets |
| ISO | International Organization for Standardization |
| JBS | Junction barrier Schottky |
| kV | Kilovolt |
| kW | Kilowatt |
| LD | Light-duty |
| MD | Medium-duty |
| MOSFET | Metal-oxide semiconductor field-effect transistor |
| Mph | Miles per hour |
| MW | Megawatt |
| MW | Megawatt |
| NEVI | National Electric Vehicle Infrastructure |
| NREL | National Renewable Energy Laboratory |
| OCPP | Open charge point protocol |
| ODBC | Organic direct-bond copper |
| OEM | Original equipment manufacturer |
| ORNL | Oak Ridge National Laboratory |
| PCB | Printed circuit board |
| PEV | Plug-in electric vehicle |
| PHEV | Plug-in hybrid vehicle |
| PI | Principal Investigator |
| PM | Permanent Magnet |
| PNNL | Pacific Northwest National Laboratory |
| R&D | Research and development |
| RDD&D | Research, development, demonstration, and deployment |
| RE | Rare earth |
| RE | Rare Earth |

| | |
|---|---|
| SAE | Society of Automotive Engineers |
| SCM | Smart charge management |
| SiC | Silicon carbide |
| SNL | Sandia National Laboratories |
| SSCB | Solid state circuit breakers |
| SST | Solid-state transformer |
| SVPWD | Space vector pulse width modulation |
| TMS | Thermal management system |
| TOU | Time of use |
| TVA | Tennessee Valley Authority |
| U.S. DRIVE | United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability |
| UL | Underwriters' Laboratory |
| UPS | United Parcel Service |
| V | Volt |
| V2G | Vehicle-to-grid |
| VTO | Vehicle Technologies Office |
| WBG | Wide bandgap |
| WPT | Wireless power transfer |
| XFC | eXtreme fast charging |

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